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THE MINERALOGICAL SOCIETY

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EXCERPT MINUTES OF COUNCIL MEETING

Held at 116 *Victoria Street, April* 3*rd*, 1884.

The Rev. Prof. Bonney, D.Sc., F.R.S., President, in the Chair.

Prof. J. W. Judd, F.R.S., was elected a Member of the Society.

EXCERPT MINUTES OF COUNCIL MEETING

Held at 116 *Victoria Street, July* 3*rd*, 1884.

The Rev. Prof. Bonney, D.Sc., F.R.S., President, in the Chair.

The following gentlemen were elected Members of the Society—

Gustav Seligmann. Herbert S. Sutton.

EXCERPT MINUTES OF COUNCIL MEETING

Held at the Museum, Jermyn Street, October 21*st*, 1884.

The Rev. Prof. Bonney, D.Sc., F.R.S., President, in the Chair.

The following gentleman was elected an Associate—

George F. Martyn, Llantrissant, South Wales.

The Meetings for next Session were arranged as follows :—

December 9th, 1884.
March 10th, 1885.
June Meeting, proposed for Glasgow, date to be fixed subsequently.
October 20th, 1885, Anniversary.

GENERAL MEETING

Held in the Library of the Museum of Science and Art, Edinburgh, June 24*th*, 1884.

Prof. Jas. Geikie, F.R.S., in the Chair.

The following papers were read :—

"Forms of Silica." By John Ruskin, D.C.L., Slade Professor at Oxford (communicated by the Local Secretary for Scotland).

[Abstract.]

In this paper the attention of mineralogists was directed to some points in the habit of crystallisation of silica, and to the relations of colour to the state of substance of minerals, which the author considered had been

hitherto entirely neglected. He asked why "large and well developed quartz crystals are frequently topaz colour, a smoke colour—never rose colour, while massive quartz may be rose colour and pure white or grey, but never smoke colour; again, why amethyst quartz may continually, as at Schemnitz and other places, be infinitely complex and multiplex in crystallisation, but never warped, while smoky quartz may be continually found warped, but never in the amethystine way—multiplex; why, again, smoky quartz and cairngorm are continually found in short crystals, but never in the long slender one—as, to take instance in another mineral, white beryl was usually short, or even tabular, and green beryl long almost in proportion to its purity."

Referring to certain structures in the specimens of agates exhibited by him, the author affirmed that all the types of undulated structure were due to crystallisation only, and expressed his opinion that the contortions of the gneiss of the Alps are not due to wrinkling by pressure, but to crystallisation. He recognises six distinct states of siliceous substance, viz. flint, jasper, chalcedony, hyalite, opal, and quartz.

"The Application of the Periodic Law to Mineralogy." By Thomas Carnelley, D.Sc., F.C.S., Professor of Chemistry Univ. Coll. Dundee (communicated as above).

"The Origin of the Andalusite-Schists of Aberdeenshire." By John Horne, F.R.S.E., H.M.'s Geol. Survey.

"On the Occurrence of Prehnite and other Zeolites in the Rocks of Samson's Ribs and Salisbury Crags." By Andrew Taylor, F.C.S., A.G.S.E. (communicated as above).

"On a New Locality for Zoisite, Loch Garve, Ross-shire." By W. Hamilton Bell, F.G.S.E. (communicated as above).

"On Diatomaceous Deposits in Scotland." By Prof. W. I. Macadam, F.C.S., Hon. Sec. G.S.E.

"Notes on the Albertite Beds of Strathpeffer, Ross-shire." By William Morrison, M.A., Academy, Dingwall (communicated as above).

Mr. Thomson referred to the fact that an allied jet mineral was found imbedded in the oil-yielding bituminous shales of Midlothian. The substance only occurred in small quantities, the largest pieces not exceeding a pound in weight; it is capable of taking a fine polish, very similar to jet—in fact a jet-worker pronounced it at first to be Spanish jet.

"Kyanite Localities in the North, and Staurolite from Preshome, Engie, Banffshire." By Thomas Wallace, High School, Inverness (communicated as above).

"Scottish localities for Actinolite." By the Rev. W. W. Peyton.

"The Crystallography of Bournonite." By H. A. Miers, B.A., British Museum, Nat. Hist. Dept.

"Notes on the Metallic Veins of the Upper Hartz, Germany." By H. M. Cadell, B.Sc., H.M.'s Geol. Survey (communicated as above).

"On some New Forms of Tourmaline from Lockport, New York County." By R. H. Solly, F.G.S.

"On Welsh Gold," from the Mawddach Valley, Merionethshire. By T. A. Readwin, F.G.S.

ANNIVERSARY MEETING

Held at the Museum, Jermyn Street, on Tuesday, October 21st, 1884.

The Rev. Professor Bonney, D.Sc.,, F.R.S., President, in the Chair.

The following were elected as Officers and Council for the ensuing year:—

President. Rev. Professor T. G. Bonney, D.Sc., LL.D., F.R.S., F.S.A., Pres. G. S.

Vice-Presidents. Rev. S. Haughton, M.D., F.R.S.
W. H. Hudleston, M.A., J.P., F.R.S.

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Foreign Secretary. T. Davies, F.G.S.

The Hon. Secretary, Mr. R. H. Scott, F.R.S., read the following Report of the Council.

REPORT.

The year which has just passed over us has been marked by an important step in the history of the Society, and one which the Council doubt not will materially conduce to its prosperity in the future. This has been the fusion with the Crystallological Society, which was carried into effect at the Special General Meeting in December last.

The Balance Sheet for the year 1883, which appeared in Part XXVI. of the Journal, shows signs of steady improvement. It closes with a Balance to Credit of £17 0s. 4d., whereas the year had commenced with an adverse Balance of £6 2s. 9d. The excess of assets over all liabilities on the 1st of January was £191 10s. 6d., being an increase of £16 11s. 5d. on the amount for the previous year.

At the present date, October, the only unpaid account for printing is that for the last No. of the Journal (No. 27). The total amount of other accounts outstanding is £12 10s., and there is a balance at the bank more than sufficient to meet it.

The number of Members shows a slight increase, owing to the election of the Members of the Crystallological Society, and in addition five new Members have been elected. The Council regret to say that two Members have been removed by death, Mr. S. F. Bawden and Prof. Q. Sella, the latter of whom has left a gap among the statesmen as well as the scientific men of Italy which it will be hard to fill. Six Members have resigned, and the names of as many more have been removed from the list for non-payment of subscriptions for three years.

The Society has held its three Meetings during the Session: two of them, in December and February respectively, have taken place, by kind permission of the Director-General of the Geological Survey, at the Museum, Jermyn Street.

The Scotch Meeting, the date of which was postponed from May 12th to June 24th in order to suit the convenience of the visitors to the Forestry Exhibition in Edinburgh, has been a brilliant success, as no less than thirteen papers were read.

Of the papers which have been laid before the Society during the Session, the Council would especially mention those by Prof. Steenstrup and the late Dr. Lorenzen on the so-called Meteoric Iron first brought by Baron Nordenskiold from the Basalt of Greenland. The Council hope that the appearance of these communications in English will attract to them a wider notice in this country than if they had remained in the original language (Danish) in which they appeared, in Part 4 of *Meddelelser om Grönland.*

Two parts of the Journal have appeared since the last anniversary, and a third is in the press in an advanced stage.

The issued parts of the Proceedings of the Crystallological Society, two in number, have been presented to the Council, and distributed to the Members.

The President then delivered his Address.

On the Motion of Mr. Scott, seconded by Mr. Hudleston, the President was requested to allow his address to be printed.

The following papers were read :—

Mr. W. Semmons, "Further Notes on Enargite."

Mr. R. H. Solly, F.G.S., "Fine Crystals of Lilac Calcite from Tankerville Mine, Shropshire."

Monsieur Guyot de Grandmaison exhibited a fine specimen of Parisite.

Mr. Rudler exhibited some specimens from the Ludlam Collection, and Mr. T. Davies some from the British Museum.

(The President's address and the papers read at the Anniversary Meeting will appear in No. 29.)

LIST OF DONATIONS.

December 1884.

Transactions of the North of England Institute of Mining and Mechanical Engineers, Vol. XXXI. Part V.; Vol. XXXII. Parts I. to V.; and Vol. XXXIII. Parts I. to VI. Presented by the Institute.

Proceedings of the Bristol Naturalists' Society. New Series, Vol. IV. Parts I. & II. Presented by the Society.

The Naturalist, Dec. 1884. Presented by the Editor.

Transactions of the Yorkshire Naturalists' Union. Part 7. Presented by the Union.

Chapters on the Mineralogy of Scotland (Chapter VII.). By Prof. M. F. Heddle. Presented by the Author.

The Mineral Resources of New Zealand. By Henry Bramwell, M.I.C.E. Presented by the Author.

On the Bingera Meteorite; on the Deniliquin or Barratta Meteorite; on the Chemical Composition of certain Rocks from New South Wales; and on Rocks from New Britain and New Ireland. All by Prof. A. Liversidge, F.R.S. Presented by the Author.

On the Discovery of Emeralds in North Carolina; on some North Carolina Minerals; and on a phenomenal pocket of fluid-bearing Quartz Crystals. By W. E. Hidden. Presented by the Author.

On Hiddenite. By E. S. Dana. Presented by W. E. Hidden, Esq.

On the Glaciation of Newfoundland. By Alex. Murray, F.R.S. Presented by the Author.

On the Iron Ores of the North-eastern part of the Jabalpur District; on New Faces observed on Crystals of Stilbite from the Western Ghâts; and on some Mineral Resources of the Andaman Islands. By F. R. Mallet. Presented by the Author.

The Science Monthly. Vol. I. No. 8. Presented by the Editor.

The American Journal of Science. Current Numbers. Presented by the Editors.

The American Chemical Journal. Edited by Ira Remsen. Presented by the Editor.

Transactions and Annals of the New York Academy of Sciences. Current Numbers. Presented by the Academy.

Proceedings of the Academy of Natural Sciences of Philadelphia. Current Numbers. Presented by the Academy.

American Journal of Mathematics. Edited by J. J. Sylvester. Current Numbers. Presented by the Editor.

Smithsonian Institution. Reports for 1881 and 1882. Presented by the Institution.

Twelfth Annual Report of the United States Geological and Geographical Survey of the Territories under Dr. F. V. Hayden. 2 Vols. with Atlas; Mineral Resources of the United States, by Albert Williams, jun.; Bulletin of the United States Geological Survey, No. I.; Second Annual Report of the United States Geolo-

gical Survey, by Major Powell; Tertiary History of the Grand Cañon District, with Folio Atlas, by Clarence E. Dutton.
Presented by the United States Geological Survey.

Reports of Progress of the Geological Survey of Canada for 1880, '81 and '82. By A. R. C. Selwyn, F.R.S. Presented by the Geological Survey of Canada.

Canadian Mining Review. Vol. I. Nos. 7 and 8. Presented by the Editor.

Reports of the Geological Exploration of New Zealand during 1882 and 1883-4. By Dr. J. Hector, F.R.S. Presented by the Author.

Journal of the Royal Society of New South Wales. Edited by A. Liversidge, F.R.S. Vol. XVI. Presented by the Editor.

Report of the Trustees of the Australian Museum, New South Wales.
Presented by the Trustees.

Report of the Chief Inspector of Mines, Victoria, for 1881.
Presented by the Inspector.

Publications de l'Institut Royal Grand-Ducal de Luxembourg, Tome XIX.
Presented by the Institute.

Annales de la Société Géologique de Belgique, Tome IX. Presented by the Society.

Bulletin de la Société Minéralogique de France. Current numbers.
Presented by the Society.

Discours prononcé par M. Daubrée aux Funérailles de M. Delesse.
Presented by M. Daubrée.

Mineralogische und Petrographische Mittheilungen, von G. Tschermak. Current Numbers. Presented by the Editor.

Zeitschrift für Krystallographie und Mineralogie, von P. Groth. Current Numbers.
Presented by the Editor.

Zeitschrift für Naturwissenschaften. Current Numbers. Presented by the Editor.

Bericht des Vereins für Naturkunde zu Cassel, XXIX. and XXX.
Presented by the Society.

Vorträge und Mittheilungen. Von G. Vom Rath. Presented by the Author.

Jahrbruch und Verhandlungen der K. K. Geologische Reichsanstalt. Current Numbers. Presented by the Institute.

Beobachtungen an Harzer Mineralien. Von Otto Luedecke.
Presented by the Author.

Krystallographische Untersuchungen an homologen und isomeren Reihen. Von Dr. Aristides Brezina. Theil I. Presented by the Author.

Ueber Melilith und Melilithbasalte, von Alf. Stelzner; Ein Beitrag zur Kenntniss der Flussigkeiteinschlüsse in Topas, von Theodor Erhard und Alf. Stelzner; Ueber die Umwandlung der Destillationsgefässe der Zinköfen in Zinkspinell und Tridymit, von Hans Schulze und Alf. Stelzner; On Crystallized Dauburite from Russell, St. Lawrence Co., N.Y., by G. J. Brush and E. S. Dana; On the Mineral Locality at Branchville, Connecticut; 4th paper, by G. J. Brush and E. S. Dana; On the elevated Coral-reefs of Cuba, by W. O. Crosby; On American Sulpho-arsenides of Mercury, by G. J. Brush; Sui Fossili del Calcare dolomitico del Chaberton, di B. Gastaldi; and a number of German Mineralogical Pamphlets. All presented by Dr. C. Le Neve Foster.

Atti della R. Accademia dei Lincei. Current Numbers of the Transunti.
Presented by the Academy.

Atti della Società Toscana di Scienze Naturali. Current Numbers.
Presented by the Society.

R. Comitato Geologico d' Italia. Current Numbers of the Bolletino.
Presented by the Institute.

Meddelelser om Grønland, udgivne af Commission for Ledelsen af de Geologiske og Geographiske Undersøgelser i Grønland. Parts 2, 3, 4, 5 and 6.
Presented by Prof. Johnstrup.

Bidrag til Kjenskab til Bræerne og Bræ-isen i Nord-Grønland, af K. J. V. Steenstrup; and Om Forekomsten af Nikkeljern med Widmannstättenske Figurer i Basalt i Nord-Grønland, af K. J. V. Steenstrup. Presented by the Author.

Mineralogiska och petrografiska Meddelander, af F. J. Wiik.
Presented by the Author.

Krystallographisk-Chemiske Undersøgelser, af Th. Hiortdahl.
Presented by the Author.

Tjenstförrättande Bergintendentens underdamga berättelse för ar 1882 (Finland).
Presented by Prof. E. H. Furnhjelm.

Censo General de la Provincia de Buenos Ayres, demografico, agricolo, industrial, comercial, &c., verificado el 9 de Octobre de 1881 bajo la administracion del Doctor Don Dardo Rocha; The Argentine Republic, by Francis Latzina; Sistema de Medidas y Pesas de la Republica Argentina; Annuaire Statistique de la Province de Buenos Ayres, Deuxième Année, 1882; La Sierra de Curá-Malal, por el Dr. Eduardo Ladislao Holmberg; and Current Numbers of the Annales de la Sociedad Cientifica Argentina. All presented by the Society.

El Comercio, Oct. 15th, 1884. Presented by the Editor.

ERRATA.

Two figures left out at page 314:—1 fig. *rutile*, line 5 from top. 1 fig. *gold*, centre of page.

Page 275, line 10 from foot, for "(of Edinburgh?—Ed.)"—*read* "of London."
,, 6 from foot, for "one" *read* "an."
Page 277, line 16 from top, for "d" and "d" *read* "λ" and "λ."
Page 278, line 9 from foot, after "of these" *read* "best seen in fig. 3."
Page 281, dele paragraph commencing "The plate shows."
Page 287, line 11 from foot, for "pored" *read* "founded."
Page 291, line 6 from foot, for "form" *read* "from."
Page 292, line 3 from foot, for "Camer" *read* "Cama."
Page 294, line 19 from foot, after "Budweis" *read* "(See Tschermak, Mineral Mitth. 1873, p. 125)."
Page 296, line 18 from top, for "Sail an ruar" *read* "Sail Roar."
Page 305, line 26 from top, after "wayboards, or" insert "perhaps."
Page 307, line 12 from foot, for "Logan rock alike" *read* "Logan" rock alike.
Page 324, line 9 from foot, for "leave" *read* "leaves."
,, line 8 from foot, for "fissile" *read* "fossil."

THE MINERALOGICAL MAGAZINE

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OF THE

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

No. 28. DECEMBER 1884. Vol. VI.

The Crystallography of Bournonite.

By H. A. Miers, M.A., Assistant in the Mineral Department, British Museum.

[Read June 24th, 1884.]

LITERATURE.

Rashleigh,	1797.	Specimens of British Minerals, Plate XIX. p. 34.
Bournon,	1804.	Philosophical Transactions, p. 30.
Smithson,	1808.	Philosophical Transactions, p. 55.
Bournon,	1809.	Nicholson's Journal, Vol. XXIV. p. 225.
Phillips,	1821.	Annals of Philosophy, Vol. XVIII. p. 360.
Haüy,	1822.	Traité de Minéralogie, IV. p. 295.
Haüy,	1822.	Traité de Crystallographie, p. 483.
Phillips,	1823.	Elementary Introduction to Mineralogy, p. 336.
Mohs,	1824.	Grundriss der Mineralogie, II., p. 561.
Dufrénoy,	1836.	Annales des Mines (III.), Tome X. p. 371.
Lévy,	1837.	Description d'une Collection de Minéraux, II. p. 406.
Mohs,	1839.	Naturgeschichte des Mineralreichs, II. p. 531.

Hausmann,	1847.	Handbuch der Mineralogie (II. Theil), I. p. 171.
G. Rose,	1849.	Poggendorf's Annalen, LXXVI. p. 291.
Brooke and Miller,	1852.	Phillips's Mineralogy, p. 201.
Kenngott,	1854.	Sitzungsberichte der k.k. Akad. Wien. XIII. p. 431.
Dufrénoy,	1856.	Traité de Minéralogie, III. p. 239.
Greg and Lettsom,	1858.	Manual of Mineralogy, p. 344.
Zirkel,	1862.	Sitzungsberichte der k.k. Akad. Wien. XLV. (1.) p. 431.
Hessenberg,	1863.	Mineralogische Notizen, V. p. 32.
Zepharovich,	1865.	Sitzungsberichte der k.k. Akad. Wien. LI. (2.) p. 108.
Schrauf,	1872.	Atlas der Krystall-formen des Mineralreiches, IV. Taf. XXXVI.
Sadebeck,	1876.	Angewandte Krystallographie, p. 120.
Zepharovich,	1876.	Lotos. (Neues Jahrbuch, p. 555.)
Quenstedt,	1877.	Handbuch der Mineralogie, p. 889.
Vom Rath,	1877.	Zeitschrift für Krystallographie u. Mineralogie, I. p. 602.
Groth,	1878.	Die Mineraliensammlung der Kaiser Wilhelms Univ., Strassburg, p. 61.
Kokscharow,	1882.	Materialien zur Mineralogie Russlands, VIII. p. 123.

The above table is a list of all publications which contain original crystallographic work, observations, or figures relating to Bournonite; it omits the names of many other works which mention the mineral, but merely contain information compiled from earlier sources; and it refers only to such works as are concerned with the crystalline form. The complete history of the crystallography of Bournonite will therefore be found in the above publications. The most important and comprehensive of these is the monograph of Zirkel published in 1862; this paper contains a summary of the previous literature and the results of many new observations, together with a large number of new figures. There is, however, a serious omission in the review of the earlier literature; no notice is taken of the earliest accurate observations made upon the mineral by W. Phillips in 1821; and it will be found that this omission leads to several errors in Prof. Zirkel's summary of previous crystallographic work, which will be mentioned in detail below.

Since the appearance of Zirkel's memoir the following authors have written :—Hessenberg on twin crystals, and new forms ; Schrauf, figures and a new form ; Zepharovich, on two new forms from Przibram ; Vom Rath on the combination of crystals from Nagyag ; Groth, a new form from Horhausen ; Kokscharow, measurement of two crystals from Neudorf.

The observations contained in the present paper are the result of a study of the collection of Bournonite in the British Museum, which is particularly rich in splendid specimens from Wheal Boys and Herodsfoot Mine in Cornwall, and contains also many fine examples from other localities, especially Neudorf, Horhausen, and Kapnik.

Figures 2 and 3 represent the general form of crystals from Endellion and Liskeard, and may be added to the numerous figures of Lévy, Zirkel, and Schrauf ; while the paper may be regarded as an appendix to the monograph of Zirkel.

Forms.—The latest complete list of observed forms is that given by Hessenberg, who mentions 48. This contains the 40 given in the table of Zirkel, and in addition 8 determined by himself. Since that time two have been observed by Zepharovich, one by Schrauf, and one by Groth. The table given by Zirkel contains 29 forms recorded by previous observers. In this table, however, as is shown below, four of Hausmann's forms and two of Mohs' are wrongly quoted, while two given by Mohs are omitted. Since in addition to this Hausmann himself was led into error in interpreting the measurements given by Phillips in 1823, it follows that these tables must be considerably modified.

It will be found that the only observations of much independent value are those of Phillips, Mohs, and Hausmann.

The measurements of Bournon were made before the reflecting goniometer had come into use, and are totally unreliable.

Those of Phillips given in 1821 are observations made upon 16 crystals with the reflecting goniometer, and those which he gives in his *Mineralogy* in 1823 are doubtless the result of further work. The work of Mohs appears to be quite independent ; Hausmann had seen the results both of Mohs and Phillips, but adds forms of his own determination. Most other tables of forms are copied from Mohs (Hartmann's, for example), with the exception of Dufrénoy's in 1856, which is unintelligible as it stands, and which is criticised below.

The following table gives a complete list of the 50 forms hitherto established, with their first observers, and at the same time a comparison between the forms of Phillips, Mohs, and Hausmann.

These refer to the editions of 1823, 1839, and 1847 respectively.

			Phillips.	Mohs.	Haus-mann.	
a	100	$\infty\breve{P}\infty$		$(\breve{P}r+\infty)s$	B	
b	010	$\infty\bar{P}\infty$	M	$(P-\infty)k$	B'	
c	001	0 P	P	$(\bar{P}r+\infty)r$	A	
τ	0 1 13	$\frac{1}{13}\bar{P}\infty$	b_1		AB' 13	
β	018	$\frac{1}{8}\bar{P}\infty$	c_1		AB 8	
t	014	$\frac{1}{4}\bar{P}\infty$				Miller.
ψ	027	$\frac{2}{7}\bar{P}\infty$	b_2		$AB'\frac{7}{2}$	
ϵ	013	$\frac{1}{3}\bar{P}\infty$				Hessenberg.
x	012	$\frac{1}{2}\bar{P}\infty$	b_3	$(\bar{P}r)\,p$	AB' 2	
h	023	$\frac{2}{3}\bar{P}\infty$		$\frac{3}{4}\bar{P}r$		
ν	034	$\frac{3}{4}\bar{P}\infty$			$AB'\frac{4}{3}$	
o	011	$\bar{P}\infty$	b_4 (c_2)	$(Pr-1)o$	D'	
σ	054	$\frac{5}{4}\bar{P}\infty$			$B'\,A\frac{4}{5}$	
z	021	$2\bar{P}\infty$	b_5		$B'\,A\frac{1}{2}$	
δ	031	$3\bar{P}\infty$				Zirkel.
ζ	041	$4\bar{P}\infty$				Hessenberg.
η	130	$\infty\bar{P}3$				Hessenberg.
e	120	$\infty\bar{P}2$	d_3	$(\breve{P}r-1)e$	$B'\,B\,2$	
l	230	$\infty\bar{P}\frac{3}{2}$	d_2		$B'\,B\frac{3}{2}$	
θ	340	$\infty\bar{P}\frac{4}{3}$				Hessenberg.
k	450	$\infty\bar{P}\frac{5}{4}$				Zirkel.
m	110	∞ P	d_1	$(\breve{P}r)d$	E	
w	430	$\infty\breve{P}\frac{4}{3}$				Miller.
a	320	$\infty\breve{P}\frac{3}{2}$			$BB'\frac{3}{2}$	
f	210	$\infty\breve{P}2$		$(\breve{P}r+1)f$	BB' 2	
i	310	$\infty\breve{P}3$				Zirkel.
d	610	$\infty\breve{P}6$				Zirkel.
Σ	301	$3\breve{P}\infty$				Schrauf.
n	101	$\breve{P}\infty$		$(\breve{P}+\infty)^2 n$	D	
γ	203	$\frac{2}{3}\breve{P}\infty$			$AB\frac{3}{2}$	
κ	103	$\frac{1}{3}\breve{P}\infty$				Hessenberg.
g	221	2 P				Zirkel.
μ	332	$\frac{3}{2}$ P				Hessenberg.
χ	334	$\frac{3}{4}$ P			$AE\frac{4}{3}$	
y	111	P	a_8	$(\breve{P}r-1)^3=(\breve{P}-1)^2 y$	P	
p	223	$\frac{2}{3}$ P			$AE\frac{3}{2}$	
u	112	$\frac{1}{2}$ P	a_1 (a_2)	P	AE 2	
ϕ	113	$\frac{1}{3}$ P				Zirkel.
v	121	$2\bar{P}2$	a_5 ?			
s	122	$\bar{P}2$	a_7 ?	P − 1		
$\odot$	123	$\frac{2}{3}\bar{P}2$	a_3 ?	$(\bar{P}-1)^{\frac{3}{2}}=(\bar{P}r-2)^5$		
ξ	124	$\frac{1}{3}\bar{P}2$		$(\bar{P}-1)^2$		
ω	436	$\frac{4}{3}\breve{P}\frac{4}{3}$				Zirkel.
ρ	211	$2\breve{P}2$				Zirkel.
π	212	$\breve{P}2$				Zirkel.
r	314	$\frac{3}{4}\breve{P}3$				Miller.
λ	414	$\breve{P}4$				Zirkel.
G	236	$\frac{1}{2}\breve{P}\frac{3}{2}$				Zepharovich.
$\mathfrak{C}$	136	$\frac{1}{2}\breve{P}3$				Zepharovich.
Δ	4 7 14	$\frac{1}{2}\breve{P}\frac{7}{4}$				Groth.

The above table requires several explanatory remarks. The figure in Phillips's *Mineralogy*, reproduced here in fig. 1, evidently represents a twin crystal, which he did not recognise as such; for the angle $c_2 : b_4$ is 60°38′ (instead of 58°28′ as calculated from the values which he gives for Pb_4 and Pc_2), and is the angle oo_1=60°32′ across the twin plane of junction. A simple juxtaposition twin crystal is shown for comparison in fig. 4 (Hessenberg's fig. 31), in which bb_1=93°40′, uu_1=4°0, mm_1=7°20′, oo_1=60°32′. The angles given in Phillips's *Mineralogy* represent actual measurements, as he is careful to state, and are not the result of any calculation; and the angles given for Bournonite are probably those obtained from the actual crystal there figured. In his paper of 1821 in *Nicholson's Journal*, the only measurements given are those which relate to the forms *a b c m o u*; and it appears that there also only twin crystals had been examined, for the angles 001 : 011 and 001 : 101 (P^1b and P^1a) are given as 43°12′ and 43°44′ respectively, and these both denote *co*.

Hence, interpreting Phillips's figure as a twin crystal, it will be seen that a_1 and a_2 are both *u* faces ($a_1\ a_2$=4°50′), d_1 and d_4 are both *m* faces, and c_2 and b_4 are both *o* planes. Then b_1 is (0 1 13) and c_1 is (018). Now these two are evidently the origin of Hausmann's (0 1 13) and (108), while c_2 is probably the origin of his (12 0 11), since (001) : (12 0 11) is 43°35′ with Hausmann's elements, and $P : c_2$=43°51′ (Phillips). Hausmann's (027) is then Phillips's b_2.

Phillips's a_5 and a_7 are probably *v* and *s*. It seems that he occasionally confuses the a_1 and a_2 of his figure, and if this is the case, a_3 may be referred to the form ⊙, and a_4 (distant 3°45′ from c_2) possibly to (1 11 11) given below as *N*. To the face a_6, which makes an angle of only 0°36′ with *u*, definite indices can hardly be assigned. Except for the confusion between a_1 and a_2, Phillips's measurements are no doubt accurate, and lead to nearly the same elements as those of Miller; but it is impossible that *MT*=90°, and there may also be a confusion between d_1 and d_4.

The table of Mohs represents his independent investigations, which are the earliest that recognise the twinning, and therefore lead to elements that are nearly correct.

Note to Table on p. 62.—In the Manuscript Catalogue of the Allan-Greg Collection (earlier than 1826) Haidinger figures *g* $(\breve{P}-2)^4$ and *z* $(\breve{P}r-2)$ as occurring on crystals from Servoz, with $(\frac{4}{3}\breve{P}-4)^{12} = (661)$ between *my* and $(\breve{P}r+2)^5$ between *uc* in the zone [*cum*]. Also $(\breve{P}r-1)^5$ from Cornwall between *uy*. Perhaps this should be $(\breve{P}r-1)^7 = p$.

Hausmann calculates his elements from the observed angles $\chi\chi'$ and mm'. With his parameters Phillips's $b_1\ c_1\ c_2\ b_2$ correspond to forms {0 1 13} {108} {12 0 11} {027} if the twinning be overlooked, so that Phillips's zone PT corresponds to Hausmann's AB. To these forms accordingly Hausmann assigns the above faces. As regards his own elements, it is impossible that the face χ can have been observed so well-developed as to be chosen for a parametral face. There may therefore have been, as has frequently been the case, a confusion between the zones cm and cb, for $m\chi = 46°15' = bo$ nearly. His faces $\nu\ \sigma\ \alpha\ \gamma$ are here retained because the angles given for them (though calculated from his elements) must represent some measured angles, and there are no forms to which they approximate more nearly than those to which he ascribes them; $AB\frac{4}{3} = (304)$ and $B'A\frac{5}{7} = (075)$ are probably u and y.

The comparative table given by Zirkel, p. 442, contains several errors. Thus Hausmann's forms {108} {203} {304} are wrongly given as {801} {302} {403}. Hausmann's {12 0 11} is referred to {11 0 12}. Mohs' $\frac{3}{4}\breve{P}r$ is ascribed to the form {430} instead of {023}. $(P-1)^2$ is ascribed to the form {121} instead of {124}, while $(P-1)$ and $(\breve{P}-1)\frac{3}{2}$ are omitted.

These errors are copied into Hessenberg's table. The forms $\odot$ and ξ, given as new by Hessenberg, had therefore been already detected by Mohs. The form Σ is given as new by Vom Rath (*N*) in 1877, but it had been previously given by Schrauf, Taf. 37, fig. 17.

Of the above forms $\psi h\nu\sigma\eta\alpha\beta\gamma\chi r$ are rejected by Schrauf.

Of these, however, $h\eta\gamma\alpha\chi$ have been observed by myself, $\psi\nu\sigma\beta$ are supported by Phillips's measurements, ψ and σ by Dufrénoy's, and r is given by Miller. Zirkel's face q [311] is here rejected on Schrauf's authority. (See Zirkel, fig. 34, and compare Schrauf's preliminary remarks on Bournonite.)

There only remains the somewhat elaborate table of forms given with measurements by Dufrénoy in his *Traité de Minéralogie*. This table, which is unintelligible as it there stands, is partly explained by his original memoir in the *Annales des Mines*, which is not mentioned by Zirkel. It will be seen from that memoir that Dufrénoy, like many of the earlier observers, took twin crystals for simple individuals, and also confused the zones [bc] and [mc]; the zone [am] he does not appear to have observed at all.

His statement that there are no angles common to the crystals from

Cornwall and Alais is enough in itself to show that there had been some confusion.

His table of measurements (uncorrected by calculation) is not quite intelligible, but the results may most probably be interpreted by the aid of the following table, in which the letters are those used in the original memoir, and not those of the transcript in the *Traité de Minéralogie*, where there are several misprints.

	Alais.	Oberlahr.	Pontgibaud.	Cornwall.	Kapnik.	Servoz.
b				*MT*	*T*	
c	*P*	*P*	*P*	*P*	*P*	*P*
o	*a*	*a*	*a*	$b_4\ c_2$		c_2
u	*cb*		*cb*	a_1		a_1
y	*bg*	*b*	*b*			
m	*MT*		*MT*	d_1	d_1	
β				c_1		
ψ				b_2		
σ		*f*			*f*	

Here the first column denotes the forms to which the faces mentioned in Dufrénoy's table of measurements are probably to be ascribed.

Finally, the crystal of Wölchite described by Kenngott in 1854, and explained by Zepharovich in 1865 as a simple individual and a combination of the forms *cabm* (304) and (705), may be in reality a twin crystal of the combination *camuy*; since approximate measurements gave $o\mathrm{P} : m\breve{\mathrm{P}}\infty = 33\frac{1}{2}°$ (=*cu*) and $\infty\breve{\mathrm{P}}\infty : m'\breve{\mathrm{P}}\infty = 39°$ (?) (=*my*).

To the above list of 50 forms must now be added 29 new forms, about which there can be no doubt, which are given in the first of the two following tables; while the second table contains 21 forms of which isolated faces have been observed, but which are not free from suspicion.

TABLE I.

Δ	015	$\frac{1}{5}\bar{P}\infty$	S	559	$\frac{5}{8}$ P
F	025	$\frac{2}{5}\bar{P}\infty$	E	558	$\frac{5}{8}$ P
R	570	$\infty\bar{P}\frac{7}{5}$	K	554	$\frac{5}{4}$ P
Π	8 11 0	$\infty\bar{P}\frac{11}{8}$	Z	443	$\frac{4}{3}$ P
M	790	$\infty\bar{P}\frac{9}{7}$	Θ	17 17 12	$\frac{17}{12}$ P
Ψ	650	$\infty\breve{P}\frac{6}{5}$	Γ	885	$\frac{8}{6}$ P
Ξ	10 3 0	$\infty\breve{P}\frac{10}{3}$	Y	535	$\breve{P}\frac{5}{3}$
Φ	410	$\infty\breve{P}$ 4	D	232	$\frac{3}{2}\bar{P}\frac{3}{2}$
L	510	$\infty\breve{P}$ 5	V	544	$\frac{5}{4}\bar{P}\frac{5}{4}$
N	1 11 11	$\bar{P}$ 11	Q	322	$\frac{3}{2}\breve{P}\frac{3}{2}$
υ	2 7 14	$\frac{1}{2}\bar{P}\frac{7}{4}$	X	473	$\frac{7}{3}\bar{P}\frac{7}{4}$
U	134	$\frac{3}{4}\bar{P}\frac{3}{2}$	T	231	$3\bar{P}\frac{3}{2}$
I	213	$\frac{2}{3}\breve{P}$ 2	W	341	$4\bar{P}\frac{4}{3}$
Ω	114	$\frac{1}{4}$ P	H	725	$\frac{7}{6}\breve{P}\frac{7}{4}$
P	10 10 19	$\frac{10}{19}$ P			

TABLE II.

097	$\frac{9}{7}\bar{P}\infty$	20 20 21	$\frac{20}{21}$ P
160	$\infty\bar{P}$ 6	18 1 19	$\frac{18}{19}\breve{P}$ 18
13 6 0	$\infty\breve{P}\frac{13}{6}$	10 1 9	$\frac{10}{9}\breve{P}$ 10
16 5 0	$\infty\breve{P}\frac{16}{5}$	20 19 38	$\frac{19}{19}\breve{P}\frac{20}{19}$
720	$\infty\breve{P}\frac{7}{2}$	11 22 34	$\frac{11}{17}\bar{P}$ 2
530	$\infty\breve{P}\frac{5}{3}$	1 0 14	$\frac{1}{14}\breve{P}\infty$
850	$\infty\breve{P}\frac{8}{5}$	638	$\frac{3}{4}\breve{P}$ 2
910	$\infty\breve{P}$ 9	12 12 11	$\frac{12}{11}$ P
17 17 11	$\frac{17}{11}$ P	312	$\frac{3}{3}\breve{P}$ 3.
14 14 11	$\frac{14}{11}$ P	104	$\frac{1}{4}\breve{P}\infty$
445	$\frac{4}{5}$ P		

Parameters.—The axial lengths deduced by the earlier observers from their measurements are criticised by Zirkel.

Expressed in terms of the elementary angles *bo*, *cn*, *am*, the elements of Bournonite as determined by the only authors who have published original observations are:

	010 : 011	001 : 101	100 : 110
Phillips ...	46°48′	43°44′	46°45′
Haüy	44·28	44·29	46·4
Mohs	46·26	41·44½	46·50
Lévy	46·28	41·42	46·50

	010 : 011	001 : 101	100 : 110
Hausmann ...	47·3	41·8	46·50
Miller	46·17	41·53½	46·50
Dufrénoy, 1856	46·48	81·32	46·50
Zirkel	46·19	41·57	46·44½

The early determinations of Bournon with the hand goniometer are valueless. Lévy (probably), Glocker, Dana, Naumann, and Quenstedt, in editions previous to 1852, copy Mohs; Beudant takes the angles from Phillips; and since 1852 the elements of Miller have usually been adopted.

It has been pointed out above that Phillips's angles are based upon a twin crystal, and that Hausmann's elements are probably to be traced to a confusion between *o* and χ.

The elements of Mohs given above are reduced to Hausmann's and Miller's axes; those of Dufrénoy are deduced from his primitive form, which is totally wrong and due to a confusion of the zones *cb* and *cn*, so that they involve very cumbersome indices even for the faces which he gives. He is wrong in stating that Lévy's primitive form is erroneous.

Haüy refers Bournonite to the same parameters as Stibnite; but his conclusion is only based on the measurement of two faces which make angles of 57° and 33° respectively with the basal plane.

The measurement of a large number of crystals with the view of ascertaining if possible how far the elements vary with the locality or the composition, has led to the belief that the parameters deduced from the best measurements upon several crystals from the same locality, or even from the same specimen, are almost exactly those of Miller. On the other hand, the angles between pairs of individual faces upon a crystal may often differ by as much as 20 minutes from the theoretical value, and individual crystals seem occasionally to require parameters differing to a slight extent from those here adopted.

But as these variations are not consistent, but are characteristic only of particular isolated faces, or at the most of particular crystals, it is very difficult to determine satisfactory parameters for any given crystal, and impossible to find any regularity in their variations. The only law observed is that while the angles in the prism zone [*amb*] are remarkably constant (as is also indicated by the close agreement of the elementary angle of previous observers in this zone), other zones, and especially the vertical zones [*cob*] [*cum*] [*cna*], are occasionally contracted or expanded, pointing to a slight increase or decrease in the vertical axis.

The elementary angles here adopted are—

bo=46°17′, cn=41°53′, am=46°50′;

corresponding to the axial ratios a : b : c=1·06612 : 1 : ·95618.

Since the table of calculated angles given by Zirkel (which is the only one of any importance yet given for Bournonite) contains 43 errors which are too large to be neglected, it has been thought advisable to give the following list of over 1,000 angles. Most of these have been calculated in two ways—(1) by the methods of spherical trigonometry, (2) by the general formula for the angle between any two faces in terms of the parameters, and the indices. (See Brezina, *Krystallographische Untersuchungen*, I. p. 306.)

It is hoped that in this way errors have been avoided. (See pp. 69-70.)

Measurements.—It will be necessary to give the measurements by which the faces of Table I. have been established, and those of Table II. supported.

∇ on a crystal from Endellion—$o\nabla$=33°7′, ox=18°11′ or 18°20′.

F and Y on a crystal from Herodsfoot Mine with $bofvs\chi\rho n\varepsilon$.

F between x and ε, xF=4°59′ Y in the zone $s\chi$, sY=23°29′.

$x\varepsilon$=7°49′ bY=67°2′.

ΠRM on a crystal from Herodsfoot Mine with $bm\theta el$—

bR=33°19′ bΠ=34°30′ bM=35°52′.

Π on another crystal from the same specimen, bΠ=34°21′.

R (two faces) on a crystal from Braunsdorf with *cumozxevbn*—

mR=9°4′, mR' (=110 : $\bar{5}$70)=77°14′.

Ψ on a crystal from Herodsfoot Mine with $bl\theta maf$ and perhaps (530) and (850), $b\Psi$=48°21′; b: 530=57°16′; b : 850=56°34′.

Ψ on a crystal from Herodsfoot Mine with $bl\theta\kappa mafi$ Φ, b Ψ=48°40′.

* Ξ on a crystal from Endellion with *cuoynabefmwia*$\rho\Sigma$. There are two faces of the form, a Ξ=17°53′, a Ξ′=17°27′

Φ on a great number of crystals from Herodsfoot Mine.

RLI on a crystal from Herodsfoot Mine with *bousy*ρ*nemf* Φ, and traces of (104), bR=33°51′, bL=77°59′, oI=38°48′, ou=28°16′, on=58°30′, a: 104=77°22′. I is a fair sized face between un.

N on a crystal from Herodsfoot Mine with *bosy*$\rho u\odot\xi mfi\Phi$ and perhaps a face (11 22 34). N is a slightly rounded face between os; and (11 22 34) lies between $\odot\xi$ in the zone $es\odot\xi$.

sN=14°34′, so=18°3′, s : (11 22 34)=12°8′, $s\xi$=18°41′, $s\odot$=11°6′.

v on several crystals from Herodsfoot Mine, bv=64°19′, uv=15°26′, are the measurements on one crystal.

* This is from one of the two specimens figured in Rashleigh's Plate XIX., the earliest described specimen of Bournonite.

		a.	*b.*	*c.*	*o.*	*m.*	*n.*	*y.*	*u.*	*s.*	*x.*	*e.*	*l.*
0 1 13	τ	90·0	85·48	4·12	39·31	86·56	42·4	49·39	30·18	42·47	21·21	86·12	86·26
018	β	90·0	83·11	6·49	36·54	85·2	42·21	47·51	28·37	40·28	18·44	83·50	84·13
015	∇	90·0	79·10	10·50	32·53	82·7	43·2	45·12	26·18	36·58	14·43	80·12	80·50
014	t	90·0	76·33	13·27	30·16	80·14	43·37	43·33	25·0	34·35	12·6	77·51	78·37
027	ψ	90·0	74·43	15·17	28·26	78·55	44·6	42·27	24·12	33·14	10·16	76·12	77·5
013	ε	90·0	72·19	17·41	26·2	77·12	44·49	41·4	23·20	31·16	7·52	74·2	75·5
025	F	90·0	69·4	20·56	22·47	74·54	45·57	39·19	22·29	28·43	4·37	71·8	72·22
012	x	90·0	64·27	25·33	18·10	71·40	47·49	37·8	22·2	25·20	51·6	67·1	68·33
023	h	90·0	57·29	32·31	11·12	66·55	51·7	34·36	23·3	21·4	6·58	60·53	62·53
034	ν	90·0	54·21	35·39	8·4	64·51	52·47	33·49	24·8	19·37	10·6	58·9	60·23
011	o	90·0	46·17	43·43	87·26	59·44	57·27	32·57	28·16	17·57	18·10	51·16	54·8
054	σ	90·0	39·55	50·5	6·22	55·59	61·28	33·30	32·31	19·1	24·32	46·1	49·26
021	z	90·0	27·36	62·24	18·41	49·44	69·50	37·21	42·7	25·41	36·51	36·39	41·17
031	δ	90·0	19·13	70·47	27·4	46·28	75·49	41·39	49·15	32·6	45·14	31·15	36·48
041	ζ	90·0	14·39	75·21	31·38	45·7	79·9	44·24	53·15	35·55	49·48	28·51	34·53
130	η	72·38	17·22	90·0	48·44	25·48	78·30	44·17	60·25	43·59	65·41	7·46	14·39
120	e	64·52	25·8	90·0	51·16	18·2	73·31	40·53	58·35	43·26	67·1	50·16	6·53
230	l	57·59	32·1	90·0	54·8	11·9	69·16	38·44	57·27	43·52	68·33	6·53	64·2
570	R	56·11	33·49	90·0	54·57	9·21	68·11	38·19	57·15	44·7	69·0	8·41	1·48
11 0	Π	55·42	34·18	90·0	55·11	8·52	67·54	38·13	57·12	44·12	69·8	9·10	2·17
340	θ	54·53	35·8	90·0	55·35	8·2	67·24	38·4	57·7	44·21	69·20	9·59	3·6
790	M	53·53	36·7	90·0	56·4	7·3	66·49	37·54	57·2	44·32	69·37	10·59	4·6
450	k	53·7	36·53	90·0	56·27	6·17	66·22	37·47	56·59	44·41	69·49	11·45	4·52
110	m	46·50	43·10	90·0	59·44	86·20	62·49	37·20	56·45	46·20	71·40	18·2	11·9
650	Ψ	41·37	48·23	90·0	62·41	5·13	60·3	37·39	56·54	48·9	73·21	23·15	16·22
430	w	38·39	51·21	90·0	64·26	8·11	58·34	38·6	57·8	49·21	74·22	26·13	19·20
320	a	35·24	54·36	90·0	66·24	11·26	57·1	38·48	57·30	50·47	75·32	29·28	22·35
210	f	28·4	61·56	90·0	71·2	18·46	53·54	41·10	58·44	54·27	78·18	36·48	29·55
310	i	19·34	70·26	90·0	76·37	27·16	51·0	45·2	60·50	59·17	81·42	45·18	38·25
10 3 0	Ξ	17·44	72·16	90·0	77·51	29·6	50·30	46·0	61·22	60·24	82·27	47·8	40·15
410	Φ	14·56	75·4	90·0	79·44	31·54	49·49	47·33	62·16	62·8	83·37	49·56	43·3
510	L	12·2	77·58	90·0	81·43	34·48	49·13	49·14	63·15	63·58	84·50	52·50	45·57
610	d	10·5	79·55	90·0	83·3	36·45	48·53	50·25	63·56	65·15	85·40	54·47	47·54
301	Σ	20·23	90·0	69·37	75·25	50·7	27·44	43·51	49·59	58·5	71·41	66·32	60·12
101	n	48·7	90·0	41·53	57·27	62·49	83·46	35·27	29·12	44·8	47·49	73·31	69·16
203	γ	59·7	90·0	30·53	51·40	69·27	11·1	36·54	24·35	41·37	39·15	77·24	74·13
103	κ	73·21	90·0	16·39	46·10	78·42	25·15	42·32	24·32	41·35	30·8	83·1	81·16
114	Ω	77·42	76·52	18·9	32·27	71·51	31·49	34·31	15·6	29·44	17·12	72·46	72·12
113	ϕ	74·6	73·1	23·36	30·13	66·24	30·7	29·4	9·39	24·59	17·42	67·37	66·52
112	u	67·58	66·26	33·15	28·16	56·45	29·12	19·25	66·30	17·32	22·2	58·35	57·27
10 19	P	67·8	65·31	34·37	28·13	55·23	29·18	18·3	1·22	16·40	22·54	57·18	56·8
559	S	66·15	64·34	36·4	28·14	53·56	29·28	16·36	2·49	15·26	23·52	55·57	54·43
558	E	64·18	62·28	39·20	28·32	50·40	30·5	13·20	6·5	14·12	26·12	52·56	51·33
223	p	63·15	61·19	41·9	28·51	48·51	30·33	11·31	7·54	13·35	27·35	51·15	49·47
334	χ	61·20	59·15	44·31	29·41	45·29	31·40	8·9	11·16	13·46	30·15	48·11	46·32
111	y	57·3	54·33	52·40	32·57	37·20	35·27	74·40	19·25	15·0	37·8	40·53	38·44
554	K	54·16	51·29	58·37	36·13	31·23	38·57	5·57	25·22	18·56	42·24	35·44	33·7
443	Z	53·34	50·43	60·14	37·13	29·46	40·0	7·34	26·59	19·50	43·51	34·22	31·36
7 17 12	Θ	52·58	50·3	61·42	38·8	28·18	40·58	9·2	28·27	20·56	45·11	33·9	30·15
332	μ	52·26	49·27	63·3	39·1	26·57	41·53	10·23	29·48	22·1	46·25	32·3	29·0
885	Γ	51·52	48·49	64·31	40·0	25·29	42·54	11·51	31·16	23·12	47·46	30·52	27·40
221	g	50·16	47·2	69·8	43·14	20·52	46·12	16·28	35·53	27·7	52·1	27·19	23·33

		a.	*b.*	*c.*	*o.*	*m.*	*n.*	*y.*	*u.*	*s.*	*x.*	*e.*	*l.*
		° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
314	*r*	56·49	78·47	35·31	43·43	58·54	13·44	25·17	15·28	31·6	35·5	65·53	62·55
414	λ	48·55	79·54	42·52	49·23	54·43	10·6	25·21	21·38	34·44	42·31	64·2	60·11
213	*I*	60·20	74·42	34·7	38·40	57·55	18·47	22·26	10·24	26·27	30·36	63·19	60·55
725	*H*	40·43	76·36	52·42	53·2	46·24	16·25	23·40	27·46	36·31	49·27	57·48	53·8
2 7 14	*v*	83·24	64·38	26·20	19·20	66·58	41·56	31·18	15·26	21·3	6·36	64·7	64·54
136	ℭ	82·19	64·41	26·36	19·41	66·14	40·59	30·22	14·16	20·27	7·41	63·40	64·20
124	ξ	78·34	64·59	27·50	21·22	63·38	37·45	27·13	10·35	18·44	11·26	62·10	62 23
4 7 14	Δ	76·58	65·9	28·29	22·13	62·34	36·25	25·56	9·0	18·11	13·2	61·34	61·35
236	*G*	74·54	65·23	29·25	23·28	61·12	34·41	24·18	6·56	17·38	15·6	60·49	60·35
436	ω	61·39	67·41	37·26	33·16	53·1	24·45	16·16	6·19	19·38	28·21	56·57	55·0
212	π	51·1	70·24	45·28	42·23	47·33	19·36	15·51	16·57	26·17	38·59	55·11	51·50
535	*Y*	52·7	66·52	46·48	39·59	45·3	23·8	12·19	16·17	23·20	38·5	51·57	48·48
123	O	75·50	58·35	35·9	17·59	56·49	38·29	21·23	10·17	11·25	15·45	54·51	55·8
134	*U*	79·40	55·1	36·55	13·5	57·16	44·22	26·14	15·11	10·56	14·25	53·29	54·28
1 11 11	*N*	86·38	46·23	43·49	3·22	57·5	54·23	29·35	25·17	14·35	18·28	49·29	51·58
122	*s*	72·3	48·54	46·34	17·57	46·20	44·8	15·0	17·32	35·54	25·20	43·26	43·52
544	*V*	50·59	57·31	56·0	39·1	34·31	33·2	6·4	23·1	21·4	42·25	40·59	37·46
322	*Q*	45·48	60·18	58·47	44·12	33·3	31·39	11·15	26·45	26·15	47·4	41·53	37·51
211	ρ	37·39	65·2	63·48	52·21	31·50	30·59	19·24	33·23	34·24	54·31	44·4	38·57
232	*D*	62·51	43·7	59·24	29·17	32·23	46·53	11·26	27·18	13·58	39·17	31·17	30·36
121	*v*	67·26	35·5	64·40	28·59	30·45	54·55	19·28	34·0	18·6	42·21	25·20	26·11
473	*X*	63·56	34·56	68·27	33·41	26·3	55·29	20·25	36·2	22·2	46·45	21·45	21·52
231	*T*	59·27	35·36	73·32	39·56	19·48	56·36	23·4	41·10	27·36	52·40	17·49	16·28
341	*W*	55·46	36·54	77·56	45·16	14·28	57·53	26·16	45·12	32·38	57·45	15·37	12·27

	a.	*b.*	*c.*	*m.*	*e.*	*l.*
	° ′	° ′	° ′	° ′	° ′	° ′
097	90·0	39·8	50·52	55·33	45·24	48·53
160	81·7	8·53	90·0	34·17	16·15	23·8
13 6 0	26·12	63·48	90·0	20·38	38·40	31·47
16 5 0	18·26	71·34	90·0	28·24	46·26	39·33
720	16·54	73·4	90·0	29·56	47·58	41·5
530	32·36	57·24	90·0	14·14	32·16	25·23
850	33·41	56·19	90·0	13·9	31·11	24·18
910	6·45	83·15	90·0	40·5	58·7	51·14
104	77·21	90·0	12·39	81·23	84·40	83·20
1 0 14	86·20	90·0	3·40	87·30	88·27	88·3
17 17 11	52·9	49·9	63·44	26·16	31·30	28·23
14 14 11	54·4	51·16	59·4	30·56	35·21	32·42
445	60·19	58·8	46·22	43·38	46·31	44·45
20 20 21	57·43	55·18	51·19	38·41	42·4	40·1
18 1 19	46·2	87·48	40·24	61·56	71·23	67·57
10 1 9	45·16	85·42	45·4	57·34	68·29	64·6
20 19 38	66·56	66·37	33·54	56·7	58·17	57·1
11 22 34	76·8	59·17	34·21	57·33	55·39	55·56
6 3 8	70·57	73·29	37·19	54·58	60·58	58·18
12 12 11	56·12	53·37	54·25	35·35	39·21	37·4
312	39·29	74·5	55·0	43·16	54·49	50·4

U on a crystal from the same specimen as the last, determined by the zones $b\xi$ and xs; also on a crystal from Endellion, fig. 5, $oU=13°6'$.

Ω on the same crystal, fig. 5, $m\Omega=71°24'$.

P (two faces) on a crystal from Herodsfoot Mine, fig. 11, mP (above)$=55°15'$, mP (below)$=55°29'$.

S on a crystal from Herodsfoot Mine with *bosyunm*, $mS=53°58'$, $my=37°20'$, $mu=56°40'$.

E on a crystal from Andreasberg between *uy*, with *nae*; it is a broad face, $uE=6°1'$, $uy=19°29'$.

$K\Gamma$ in a zone containing *myu* and perhaps (12 12 11) on one of a wheel-shaped group of crystals from Herodsfoot Mine, $mu=56°37'$, $my=37°16'$, m : 12 12 11$=35°0'$, $mK=31°11'$, $m\Gamma=25°46'$.

Z in a zone containing $g\mu y$ and perhaps (14 14 11) on a crystal from Herodsfoot Mine which has also the face *o* well developed, $oy=32°56'$, $yg=16°20'$, $y\mu=10°6'$, $yZ=7°51'$, y : (14 14 11)$=6°17'$, $og=43°8'$, $o\mu=38°48'$, $oZ=37°22'$, o : (14 14 11)$=36°26'$.

D on a crystal from Endellion with *boxuygmvs*; it occurs as a small dull face between *yv* and nearly between *sg*, $yD = 12°12'$ about.

V as a good bright face between $y\rho$ with $n\Sigma vQ$ and perhaps (18 1 19) on a crystal from Endellion. *V* gives two images, $y V=6°11'$ or $5°44'$, $y\rho=19°16'$, $nV=32°57'$ or $33°9'$. *Q* is a small face not quite between *V* and ρ. $yQ=10°51'$, $nQ=32°35'$; and (18 1 19) occurs as a small face beyond *n* in the zone $[\rho n]$ on the broken edge of the crystal, n : (18 1 19)$=2°19'$, $n\rho=30°58'$.

Q (2 faces) on a crystal from Endellion with $cn\Sigma u\rho ymfoa$; it occurs as a large bright face between ρy, $yQ=11°13'$, $yQ'=11°20'$, $cQ=58°42'$.

Also (2 faces) on another crystal from Endellion with $n\Sigma u\rho ymb$, $yQ = 11°17'$, $yQ'=11°8'$, $nQ=31°37'$, $bQ=60°13'$, $bQ'=60°25'$, and also on other crystals from Endellion.

XTW on two crystal fragments from Kapnik; the specimen has bright bacillary groups of Bournonite dispersed upon Freieslebenite.

One fragment (twinned) is shown in fig. 6, on which $oW=45°8'$, $oT=40°4'$, $oX=33°36'$. The other fragment has the faces $b\odot vW$, $bW=37°9'$, $vW=16°12'$.

H on a twin crystal from Neudorf, fig. 7, the face gives two images—$cH=52°22'$ or $52°45'$, $nH=16°8'$ or $16°34'$.

(097) on a crystal from Herodsfoot Mine as a bright but striated face between *bo*, with *bosu*—$bo=46°7'$, b : 097$=38°55'$.

(160); on the edge bb_1 of a twin crystal from Servoz is a face between ba_1, $ba_1=3°33'$, b : (160) $9°0'$, $bb_1=93°35'$.

(13 6 0). A crystal from Neudorf with the forms *abelθmμno* contains a twin lamina consisting of y_1 (between two *y* faces of the first crystal) and a prism face *j* (13 6 0)? (fig. 8), $yy_1=5°50'$ (calculated=5°50'), $yj=41°56'$ (calculated 41°55').

(13 6 0) (16 5 0) on a crystal from the same wheel-shaped group from Herodsfoot Mine which yielded *K*Γ (see above) with *bmfi*, $bm=43°13'$, $mf=18°42'$, m : (13 6 0)=20°36', $mi=26°29'$, m : (16 5 0)=28°29'.

(720). A crystal from Endellion (twinned) has the forms *n m u o a* and another prism face, $ma=46°43'$, a : (720)=16°45'.

(910) on the same crystal mentioned above, as showing two faces of the form Ξ, a : 910=6°55'.

Θ and (17 17 11) on a crystal from Herodsfoot Mine in a zone containing $m\mu y$, m : (17 17 11)=25°55', $m\mu=26°23'$, $m\Theta=27°44'$, $my=36°55'$; on the same crystal $bo=46°8'$, $bm=43°10'$.

(445) on a crystal from Endellion as a curved face, m : (445)=44°42' to 42°52', $my=37°28'$.

(1 0 14) on the same crystal with the forms *boxuy*⊙*ξnemyρ*,

n : (1 0 14)=38°11'.

(20 20 21) on a crystal from Endellion with *muyoxξ*, $mu=56°37'$, m : (20 20 21)=38°35', $my=37°25'$, $oy=32°45'$, o : (20 20 21)=32°13'.

(10 1 9) on a crystal from Neudorf with *cuuym*, and perhaps a face of (18 1 19), m : (10 1 9)=57°21', $mn=62°42'$; u : (18 1 19)=26½°, $un=29°56'$ about.

(14 14 11) and *Z* (2 faces) on two juxtaposed crystals from Herodsfoot Mine in the zone *my*, one crystal gave $my=37°20'$, $mZ=29°55'$, $m\mu=27°10'$, $mg=21°1'$, $mg'=20°53'$, $m\mu'=26°56'$, $mZ'=30°6'$. The other gave $my=37°39'$, m : (14 14 11)=31°14', $m\mu=27°12'$.

(20 19 38) on a crystal from Herodsfoot Mine with *boxsu*, $ux=27°48'$, u : (20 19 38)=1°28' (calculated=1°2').

Indications of the forms (638) (312) (403) have also been observed.

(638) on a crystal from Herodsfoot Mine in the zone ρf, $\rho f=26°10'$, ρ : 638=25°52' (calculated=26°30').

(403) in the zones [$l\rho$] and [an] on a crystal from Neudorf.

(312) in the zones [nm] and [xa]. Locality doubtful.

Also a rounded face between u and ρ on a crystal from Herodsfoot Mine, to which indices could not be assigned.

As examples of measurements from very good crystals the following are added:—

I. (Cornwall). $bf=61°50\frac{1}{4}'$, $be=25°7\frac{1}{2}'$, $b\Phi=75°16'$, $f\rho=26°16'$.

II. (Cornwall). $bm=43°3\frac{3}{4}'$, $bl=31°48\frac{1}{2}'$, $bm'=43°10\frac{1}{2}'$, $bo=46°17'$.

III. (Cornwall). $ou=28°22\frac{1}{4}'$, $bm=43°9\frac{1}{2}'$, or $43°10\frac{1}{4}'$, bb_1 (twinned) = $93°42'$.

IV. (Cornwall). $bo=46°9'$, $bs=48°46'$, $bu=66°28'$, $y\rho=19°24'$, $ys=15°0'$, $s\xi=18°41'$.

V. (Cornwall). $oy=32°44'$, $om=59°39'$, $oy'=92°6'$, $ox=18°16'$, $ev=25°20'$, $bm=42°56'$, $f\rho=26°11'$.

VI. (Oberlahr). $cu=38°17'$, $am=46°51'$, $an=48°3'$, $a\Sigma=20°24'$, $ay'=57°4'$, $cy'=52°39'$, $cu'=33°14'$, $mn=62°49'$.

Of the forms given in the first comparative table, all have been observed during the course of the present study of Bournonite, with the exception of $\tau\beta\psi\nu\zeta\lambda G$ ℄ Δ.

Twin-growth.—The subject of Bournonite twins has been so carefully studied by Hessenberg, and so many figures have been given by him and by Schrauf, that the main facts do not require to be re-stated.

The general conclusions drawn from the present examination are—

I. That composition may be either parallel or perpendicular to the twin-plane, but is generally the former.

II. That the twinned crystals are always united by juxtaposition, and not by interpenetration.

The simplest possible case of a twin crystal showing *abc* as predominating faces will therefore be fig. 4, in which $aa_1=86°20'$, $bb_1=93°40'$, $mm_1=7°20'$.

The corresponding figure with composition perpendicular to the twin-plane is shown in fig. 13, in which

$$aa_1=93°40',\ bb_1=86°20',\ mm_1=0°0'.$$

Figure 4 may be taken as the elementary type of Bournonite twinning; the composition is generally repeated with parallel twin planes *m*, so as to give rise to a number of twin laminæ (compare Hessenberg, fig. 32). The twin structure of crystals from Neudorf, Horhausen, Endellion, and many other localities seems to be generally of a simple character, and to be complicated mainly by the occurrence of twin laminæ.

But the case of the wheel-shaped groups of Herodsfoot Mine and the Rädelerz of Kapnik requires a somewhat more detailed description, because it is left doubtful by Hessenberg, and has been variously explained.

Zirkel regards the Rädelerz as composed of a number of long thin individuals which cross one another like the spokes of a wheel, each one united with some other by the ordinary twin law (twin face *m*). He also suggests that the structure results from a central cross composed of two

interpenetrating individuals, upon the arms of which are grouped other crystals in twin-position (*cf.* his fig. 39).

Sadebeck (*Angewandte Krystallographie*, p. 120) regards the crystals from Cornwall as interpenetration twins, in which the cruciform structure is not generally apparent because the spaces between the arms are filled up by other individuals twinned upon them. In the crystals from Cornwall and from Siebenbürgen (Transylvania), he says that each cross may be succeeded by another inclined to it at an angle of 3°40′. In this way he suggests that the Rädelerz may be composed of as many as 23 individuals, and 46 rays.

Hessenberg, although he states that he has not observed a genuine interpenetration twin, supposes the Herodsfoot crystals to afford an example of such. The Rädelerz of Kapnik and other complicated groupings he explains as circularly repeated juxtaposed twins bounded by *a* and *b* as the predominating faces in the prism zone, and formed by individuals which may have either (1) their brachy-diagonal, or (2) their macro-diagonal axes radiating from the centre of the compound crystal. Compare Hessenberg's figures 27 and 24. He states in consequence, "Wenn man am Goniometer den Winkel von 172°40′ ein-oder aus-springend in der horizontalen Zone auffindet, so dient er als der sicherste Leitfaden, da es die den Zusammensetzungsflächen paarweise nächst benachbarten Flächen *m* sind, welche zwischen sich mit diesem Werthe geneigt sind."

Quenstedt describes the groups from Cornwall and from Nagyag as interpenetration twins ; the Rädelerz of Kapnik and the discs of Cornwall as parallel growths.

The conclusions drawn in the present paper are to some extent at variance with the above explanations, but are based only upon the specimens in this collection.

The suggestions of both Zirkel and Sadebeck start with the idea that the cruciform interpenetration twin is the elementary form, whereas it appears very doubtful whether such a twin of Bournonite has been observed.

The following is perhaps the clearest method of considering complicated twin crystals of Bournonite.

Each successive twinning has the effect of inclining the axes of two individuals at an angle of 3°40′ to one another. It will then be seen that if any number of individuals be ranged beside one another by repeated twinning with inclined twin planes, their axes, and therefore the planes *ab*, will always be inclined to one another at multiples of 3°40′, and their *m* planes at multiples of 7°20′. An uneven number of twin repetitions will

bring a of one individual in a neighbouring position to b of another, an even number of repetitions will bring two a or two b faces into neighbouring positions. This will be seen from fig. 14, in which a_1 b_1 is the first position of the axes, m_1 the first twin axis; a_2 b_2 the second position, m_2 the second twin axis, and so on. A measured angle between two a and b faces, or between an a and a b face, will therefore denote at once the number of twin repetitions to which it corresponds.

Thus the angle b_4 b_5=14°40′ (=4×3°40′) of Hessenberg's fig. 26, denotes 4 repetitions; the angle a_1 b_4=11°0′ of his figures 24, 27, and 30 denotes 3 repetitions.

Now in the present examination of the Kapnik Rädelerz, it has generally been found that the angle 7°20′ is that between two a or two b faces, and not between two m faces, as stated by Hessenberg; and that the predominating faces are generally m, and not a or b, while the predominating faces upon the edges of a disc of Rädelerz are almost always u, and not o or n, as they are usually represented in figures.

Thus a cruciform crystal of Rädelerz will be represented by fig. 10. But these groups are far more commonly composed of three or more individuals united, as in fig. 9. II. is twinned upon I., III. is twinned upon II., the twin-planes being shown by dotted lines. I. and III. are therefore irregularly united, and a_1 a_3 7°20′.

Fig. 9 may therefore be added to figures 24, 26, 27, 30, of Hessenberg and figures 15 and 17-21 of Schrauf as a frequently observed mode of combination. The number of individuals, however, varies from 3 to 6 or 7. It may be mentioned that the only safe method of determining the positions of the individuals is by means of the faces *onuy*, &c. From an observation of the prism zone alone it is almost impossible to discriminate between them: 86°20′ or 93°40′ may be the angle between two m faces of one individual; 7°20′ may represent the m faces of a pair of individuals once twinned, or two a or b faces after double twinning; and a b m are all smooth bright faces.

The mode of twinning most common in the Bournonite from Liskeard is totally different. The ordinary form of the individuals is that of fig. 11 (without the faces P) or of fig. 3. Two such crystals are usually united as in fig. 12, so that bb_1 = 86°20′, while the two rounded and uneven a faces form a reentrant angle on the inner side of the group. On the outer side the crystals are bounded by the largely extended m faces, as shown in fig. 12, and thin laminæ may generally be traced on these parts of the crystals. The twin-plane is shown by a dotted line. This at first sight appears to be scarcely a case of composition perpendicular to

the plane of twinning; it might be, in fact, because the crystals do not unite regularly otherwise than *along* the twin plane that the Herodsfoot crystals adopt this form; so that the two individuals do not come into contact at all, but break out directly from the mass of the Bournonite, having the direction of the dotted *m* plane in common.

To this reluctance, if the term may be used, of two crystals to combine perpendicular to the plane of twinning (where two *m* planes with a tendency to coincide would be inclined at an angle of 7°20′*) may perhaps be ascribed the distortion of the crystals, and especially of the *a* faces near their junction, also the tendency to grouping of other crystals on the outer side of the two principal individuals, as indicated in fig. 12 (b_2), and the oscillatory twinning at the outer corners.

But, on the other hand, in many cases, and especially in the more nearly circular discs, there appears to be no vacant reentrant angle between the two *a* faces; the crystals come into complete contact, and the two *m* faces, though uneven, often fall into a plane; so that the Herodsfoot crystals must be regarded as presenting a real example of composition perpendicular to the plane of twinning.

Where there is a reentrant angle between the two *a* faces, as in fig. 12, it is generally occupied by a small columnar crystal, either parallel to one of the two larger individuals or twinned on one of them, or it may be itself a compound crystal. The crystals which often range themselves in a long series on the outer sides of the two principal members, nearly parallel to them, have abrupt contact along the uneven face *a*, as shown. The figure also indicates the uneven nature of the face *o*, and the way in which ξ, v, frequently run out from *u* across *o*. A roughly cruciform figure would be produced by the symmetrical repetition of fig. 12 across the dotted line *m*; this is the foundation of the cruciform or circular discs from Herodsfoot, the form being complicated by the grouping of other nearly parallel portions of crystals about these individuals.

Finally then it may be concluded that the twinning of Bournonite is by juxtaposition, and not by interpenetration (*cf.* also Schrauf's figures, which mostly point to the same conclusion); that composition perpendicular to the twin-plane is not rare on Cornish crystals; that the Kapnik Rädelerz is complicated more by parallel repetition than by twinning, the number of individuals rarely exceeding 5; and that figs. 9 and 10 are a more truthful representation of the complicated and cruciform crystals

* "It may be noticed that in the case of Aragonite, with which the twin crystals of Bournonite are often compared, this angle is 52°20′."

than those generally given: it may be added that specimens which have repeated twins with inclined planes do not often show signs of twin lamination or repetition with parallel planes.

Irregular Conjunction.—The paper of Vom Rath quoted above deals with the case of four crystals, which have their *c* faces parallel, but are not twinned; this mode of combination frequently occurs, and complicates the true twins to a large extent; three examples based upon good measurements, and chosen from many observed, are

$$aa_1 = 81°29'; \quad bb_1 = 82°41'; \quad bb_1 = 88°12'.$$

Another irregularity which often introduces a fresh difficulty into the Rädelerz is a tendency to twist, which the crystals show both in the compound groups of Kapnik and those of Herodsfoot, so that the individuals form part of a helix about the vertical axis, and their prism faces do not fall into the same zone.

Zones and Faces.—A few notes may be added on the relative development of the principal zones and their faces.

[*amb*]. *a* is generally smooth and bright (except from Liskeard); *b* is very bright, finely striated parallel to the edge *bo*, and sometimes formed of step-like projections running horizontally; *m*, bright, striated vertically, as are also most of the prism faces, especially those between *ma*. Some crystals from Wolfsberg, Kapnik, Mexico, and Liskeard, are columnar, owing to the predominance of this zone.

Some of the crystals from Neudorf, Endellion, &c. have only *amb*, but as a rule those from Endellion show *belma*, while crystals from Herodsfoot Mine are particularly rich in faces between *m* and *a*, Φ being characteristic. On some crystals from Neudorf the zone is not represented.

The faces in this zone are sometimes curiously fretted, and have a worm-eaten appearance; this is due to the recurrence on the prism planes of those faces *osyuρ*, &c. which may be common on the crystals.

[*moun*]. This zone (in which one index is equal to the sum of the other two) is of special importance, owing to the twinning; and the recurrence of twin laminæ causes a striation of the faces parallel to their edges.

o is, after *b*, the brightest and commonest face of Bournonite. It is generally horizontally striated. On Liskeard crystals this face is often either very uneven and dull, or replaced by an uneven concave surface.

u is sometimes bright, sometimes dull; when the *u* faces of two individuals are brought into conjunction by twinning, one is often bright and the other dull.

n, which is one of the commonest faces on the Neudorf crystals, is

frequently missing on Cornish specimens, owing to twinning, which brings the zone *cob* into prominence; it is smooth and bright.

The part of the zone represented by *WTX* is only to be observed upon specimens from Kapnik in which bright Rädelerz is dispersed upon crystallised Freieslebenite. As is shown in fig. 6, there is no inducement of these faces on an edge, but they run down as a bright tongue towards the prism zone; they are slightly striated parallel to their edges.

[*cob*]. The faces in this zone are generally horizontally striated; *x* is common, and the edges *ox*, *xc*, are often uneven and replaced by uneven faces.

c is for the most part smooth and bright, and in Kapnik Rädelerz, when smooth, scarcely shows any trace of twin demarcations, except a slight striation parallel to the edge *co*; but on some crystals, especially those from Liskeard, *c* is replaced by an uneven rounded surface tending to form itself into faces towards *x* and *o*. Faces between *b* and *o* are rare, the edge *bo* being sharply defined.

[*osyρ*]. This zone is especially characteristic of the Liskeard crystals (see fig. 11), in which *s* is sometimes dull, while *y* and *ρ* are always very bright.

s is generally quite dull, and especially on Neudorf crystals, where it is a large face.

y, always bright, occurs either as a thin face between *um*, or between *yρ*, or else with nearly rectangular edges on the edge *on*.

[*anκ*]. *N* is usually the only face in this zone between *ao*, and is uniformly smooth; of the others, *κ* is most frequent.

[*uym*]. *uym* are the common faces; the zone sometimes occurs, especially in Cornish crystals, as a series of horizontally striated but bright planes: examples have been given above.

Of other faces *v* (bright) is especially characteristic of Endellion, *υ* (dull) of Liskeard crystals.

Finally, a glance at the projection will show a noteworthy fact about the zones. In the zone [*ac*] the intercepts made on the axes by the common faces are exclusively multiples of 3; in the zone [*bc*] the only common faces are *oxtz*, so that the intercepts are generally multiples of 2; in the prism zone, where the common faces are *eiθwafiΦd*, they seem to be a combination of both.

EXPLANATION OF PLATES.

Plate I.

Fig. 1. Figure of Bournonite from Phillips's Mineralogy.
Fig. 2. Type of crystals from Endellion.
Fig. 3. Type of crystals from Liskeard.
Fig. 4. Twin crystal, combined parallel to twin-plane.
Fig. 5. A crystal from Endellion.
Fig. 6. A crystal from Kapnik.
Fig. 7. A crystal from Neudorf.
Fig. 8. A crystal from Neudorf.
Fig. 9. Type of 3-lings from Kapnik.
Fig. 10. Type of cruciform crystals from Kapnik.

Plate II.

Fig. 11. A crystal from Liskeard.
Fig. 12. Type of twin crystals from Liskeard.
Fig, 13. Twin crystal, combined perpendicular to twin-plane.
Fig. 14. Scheme of Axes in repeated twin crystals.

X. *On the Tetartohedral Development of a Crystal of Tourmaline.*

By R. H. Solly, F.G.S., Demonstrator of Mineralogy in the University of Cambridge.

[Read June 24th, 1884.]

In working on the isomorphism of Tourmaline I have been struck by the very peculiar development of a fine crystal from Pierrepont, New York, now in the Cambridge Collection.

The crystal is doubly terminated, of a jet-black colour and splendid lustre. It weighs 314.83 grammes, and measures $1\frac{1}{5}$ inch by 1 inch by $\frac{1}{2}$ inch.

The forms present are $r\ \kappa\ \{100\}$, $\bar{r}\ \kappa\ \{\bar{1}00\}$, $s\ \kappa\ \{\bar{1}11\}$, $\bar{e}\ \kappa\ \{0\bar{1}\bar{1}\}$, $u\ \kappa\ \pi\ \{3\bar{2}0\}$, $b\ \kappa\ \{2\bar{1}\bar{1}\}$, $\bar{b}\ \kappa\ \{\bar{2}11\}$, and $a\ \{10\bar{1}\}$.

Fig. I. is a stereographic projection of the poles of the faces present.

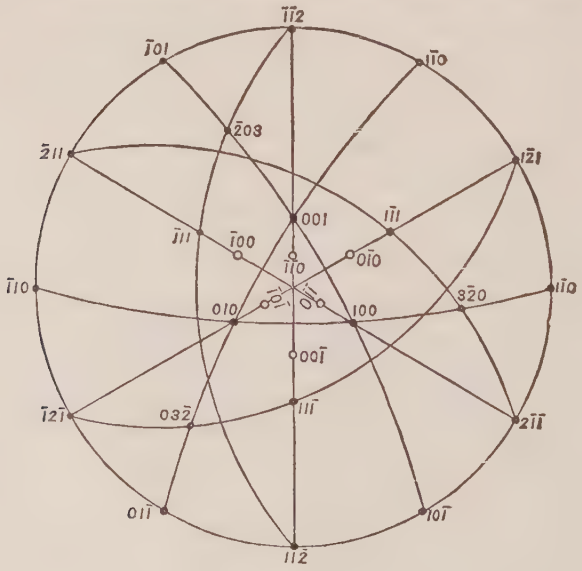

Fig. I.

Figures II. and III. are drawn so as to show in two positions the development of the faces.

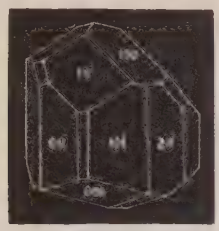

Fig. II.

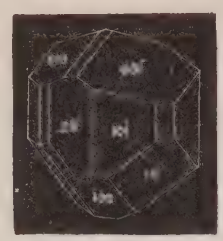

Fig. III.

The form r has all its faces present, but the parallel faces are thrice as large.

The form s is only present with the smaller r faces, and is entirely absent at the other end of the crystal (Fig. II.).

The form e is a narrow plane only present with the large r faces, and is entirely absent at the other end of the crystal (Fig. III.).

The form b has all its faces present, but its parallel faces are unequally developed.

So far the crystal is but a fine example of hemimorphic development, the parallel faces being wanting or very unequally developed.

But u, a scalenohedral form which ought to exhibit holohedrally twelve faces or hemihedrally six faces, appears with only three faces on this crystal, which are all at one extremity of the axis, and arranged in the manner of similar planes on apatite or quartz.

The question then arises: are the three faces which are thus alone found a true tetartohedral development of a scalenohedron; and are we to deduce it from the law of apatite or the law of quartz, since geometrically, on account of the hemimorphic development, it may belong to either?

Though such tetartohedrism is not known to occur on any native mineral, it has been observed on the crystals of an artificial salt.

Groth has described (*Pogg.* 137, 436) crystals of sodium super-iodate (Na I) O_4+3 aq. which exhibit tetartohedrism.

But, since these crystals rotate the plane of polarisation, Groth considers them as examples of a hemimorphic development of an asymmetric hemihedral crystal, like quartz.

As crystals of tourmaline do not rotate the plane of polarisation, it is probable that in the case of the present crystal the hemimorphic development is of a semiform, similar to those which have been observed on dioptase and apatite, and that the form should be designated crystallographically as $u\ \kappa\ \pi\ \{3\bar{2}0\}$.

Though it may be rash to accept a tetartohedral development of tourmaline from the observations of one crystal, still it must be remembered that scalenohedral forms are the only ones which render the observation possible, and that such forms are extremely rare ; and, moreover, that the presence of six planes of the scalenohedron at one end of the axis does not necessarily militate against such a view, unless it be shown that these planes are similar in their physical characters.

I have examined several crystals from Pierrepont in different collections; the planes u are fairly common in these crystals, but that of the Cambridge collection is the only one in which three planes of the form alone exist ; generally it seems as if six planes occurred together at one end of the axis.

Perhaps the observation is sufficiently interesting to justify my calling the attention of crystallographers to it.

The crystal has been measured on a Fuess goniometer with the highest power, and good measurements were obtained, from which the following element was calculated :— $r\ o = 27°36\frac{1}{2}$.

	Found.	Calculated.
$s\ s_1$ =	77°·29′	77°·30′
$r\ r_1$ =	47°·20½′	47°·20′

The pyro-electric property has been tested, and it has been found that while cooling, the end on which the half form s appears is the antilogous pole, and the opposite end, on which the half form e appears, the analogous pole.

The specific gravity was found to be 3.145.

XI. *Application of the Periodic Law to Mineralogy.*

By Thos. Carnelley, D.Sc., Prof. Chemistry, University College, Dundee.

(Communicated by the Rev. W. W. Peyton.)

[Read June 24th, 1884.]

THE Periodic Law of the Chemical Elements first foreshadowed by Newlands, and subsequently developed by Mendeleeff and Lothar Meyer, states:—(1) *The Properties of the Elements are a Periodic Function of their Atomic Weights.* (2) *The Properties of the Compounds of the Elements are a Periodic Function of the Atomic Weights of their Constituent Elements.* This law was explained and illustrated by several examples in the case of both chemical and physical properties, and attention specially directed to the division of the elements, as arranged in Mendeleeff's table (Ann. Chem. Pharm.; Suppl. 1870-72, p. 151) into odd and even series, and to the somewhat peculiar character of the eighth group of that table. These points were further illustrated by a reference to Lothar Meyer's curve of the elements (Mod. Theor. der Chem.).

In applying the Periodic Law to Mineralogy, it was pointed out that this could not be rendered so evident as could be wished, since the relationships brought to light by the application of that law in ordinary chemical science referred to chemically pure substances, whereas mineralogy dealt chiefly with bodies whose properties were liable to some variation, owing to their almost always containing more or less of other compounds foreign to their ideal composition, so that any exact relationships which may exist between their composition and general chemical and physical properties are in many cases concealed.

The principal lines indicated in which an application of the Periodic Law to Mineralogy may be of service were as follows:—

(1.) *Reducibility of the Elements to the Free State from their State of Combination. Elements belonging to* odd *series are, as a rule, easily reducible to the free state, whilst those belonging to* even *series are only reducible to the free state with difficulty.*

(2.) *Occurrence of the Elements of the Free State in Nature.* This is, of course, closely connected with the property of reducibility already considered, so that we may expect a similar relation to hold good. *Elements belonging to* even *series (except C, N, O, and Group VIII.)*

never *occur in the free state in Nature, whereas elements belonging to* odd *series* generally *and* sometimes frequently *do occur* free.

(3.) *Occurrence of the Elements in the Combined State in Nature.* In reference to what is said under this section, F, Cl, Br and I, and the elements of Group VIII. must be neglected. They are referred to below.

Elements belonging to odd *series usually occur in Nature as sulphides or double sulphides (also as selenides, tellurides and arsenides), i.e. in combination with a negative element belonging to an* odd *series, and only in very few cases as oxides, whereas elements belonging to* even *series, on the other hand, usually occur as oxides or double oxides (forming silicates, carbonates, sulphates, aluminates, &c.), i.e. in combination with a negative element belonging to an* even *series, and never (with two exceptions) as sulphides.*

Thus:

Elements belonging to even *series:—*

As oxides, or double oxides	*Commonly.*	Li (Lithia mica, &c.), K (nitre, felspar, &c.), Rb, Cs, Be, Ca, Sr, Ba, B, Sc, Y, La, Yb, C, Ti, Zr, Ce, Th, V, Nb, Di, Ta, O, Cr, Tb, W, Mn.
	Frequently.	N (in nitre), Mo.
	Rarely or never.	None.

The only two of these elements occurring as sulphides are:—

	Commonly.	Mo.
	Very rarely.	Mn (also O, as SO_2 in volcanic gases).

Elements belonging to odd *series:—*

As sulphides (selenides, tellurides)	*Commonly.*	Cu, Ag, Zn, Cd, Hg, Ga, In, Tl. Pb, Sb, S, Se, Te.
	Frequently.	As, Bi, Sn.
	Never.	Au (occurs only in free state in Nature), Na, Mg, Al, Si, P (for these see Meyer's curve).
As oxides	*Commonly.*	Na, Mg, Al, Si, P (for these see Meyer's curve) and Sn.
	Frequently.	Zn, Cu.
	Rarely.	Pb, Sb, Bi, As.

Group VIII.—The elements of this group, except Fe, Co, and Ni, never occur in Nature in the combined state, and therefore need not be considered in this connection. As regards the first triad of this group—

Fe occurs *mostly* as oxide, but also *frequently* as sulphide.

Co occurs *mostly* as sulphide and arsenide, but *sometimes* as oxide.

Ni occurs *almost always* as sulphide and arsenide, and only *very rarely* as oxide.

Iron, the first member of the triad, thus more nearly resembles elements of the even series; whereas Nickel, the last member, more nearly resembles elements of the odd series. This shows, therefore, in a marked manner that in Group VIII. we have a gradual passage from even series on the one hand to odd series on the other.

The halogens Cl, Br, I and F, being the most electro-negative of the elements, occur in nature in combination with the most electro-positive metals as chlorides, bromides, iodides and fluorides, &c. and are never (if we omit a few metallic oxychlorides and sulphochlorides) found in combination with either oxygen or sulphur.

The only other point necessary to mention is that as regards the odd members of any one group, the tendency to occur in nature as sulphides increases, whereas the tendency to occur as oxides or double oxides diminishes, as the atomic weight increases, thus :—

Group I.	Na*	frequently occurs as double oxide (silicates, Chili saltpetre, &c.), and never as sulphide.
	Cu	occurs commonly both as sulphide (Cu_2 S, Cu S, Cu Fe S_2, &c.), and as oxide or double oxide (Cu_2 O, Cu O, malachite, &c.)
	Ag	generally as sulphide and never as oxide.
	Au	only in free state.
Group II.	Mg	always occurs as double oxide (Mg CO_3, &c.) and never as sulphide.
	Zn	most commonly occurs as sulphide, but sometimes also as oxide.
	Cd	only found as sulphide and never as oxide.
	Hg	only found as sulphide or in metallic state, and never as oxide.
Group IV.	Si	always occurs as oxide or double oxide (silicates).
	Sn	almost always occurs as oxide, but sometimes as sulphide.
	Pb	almost always occurs as sulphide, and only rarely as oxide (minium).

And a similar thing for groups III. V. and VI.

The whole of the above facts may be expressed in terms of Lothar Meyer's curve as follows :—

Elements standing on falling *portions of the curve are reducible with difficulty, and never occur in the free state in Nature, or in combina-*

* Omitting its occurrence as chloride, since it does not affect the present question.

tion as sulphides, but always in combination with oxygen, forming oxides or double oxides (silicates, sulphates, carbonates, &c.), whereas elements standing on rising *portions of the curve are easily reducible and almost always occur (more or less) in the free state in Nature, and also in combination with sulphur and but rarely with oxygen.*

4. *The hardness, specific gravity, and fusibility of the elements* also vary periodically with the atomic weight, as is best seen by reference to Meyer's Curve.

5. *The hardness and specific gravity of compounds* (occurring as minerals). So far as data will allow of a conclusion we have the following relationships. (*a.*) *Sulphides of the elements of odd series.* The specific gravity of the natural sulphides of the elements in any one *group* increases with the atomic weight, whilst the hardness diminishes. The specific gravity of the sulphides of the elements in any one *series* diminishes as we pass along the series from the positive to the negative end, whilst the hardness increases up to the middle of the series and then diminishes. (*b.*) *Oxides of the elements of odd and even series.* The specific gravity of the oxides of any one group of even or of odd elements (odd not being comparable with even elements) increases with the atomic weight.

6. *Colour.* (*a.*) As shown by Mr. Ackroyd, many bodies when heated undergo alterations in colour, such that as the temperature rises the colour passes more and more towards the red end of the spectrum, and finally, if the temperature be high enough, to brown and black. (*b.*) As also shown by Ackroyd, an increase in the quantity of the electro-negative element in a simple binary compound produces a colour change toward the red end of the spectrum.

(*c.*) The influence of atomic weight on the colour of compounds may be stated thus:—*Take any series of compounds* A_xR_y, B_xR_y, C_xR_y, *&c., in which R is any element or group of elements, whilst A, B, C, &c., are elements belonging to the same sub-group of Mendeleeff's Table of the Natural Classification of the Elements. Then as the atomic weight of the elements A, B, C, &c., increases, the more does the colour of the compound pass towards the red end of the spectrum, and then (in many cases) to brown and black.*

In conclusion, a theory was propounded whereby these colour relationships are apparently fully accounted for.

Finally, it should be said that the points mentioned in the paper were brought forward rather as suggestions for future research than as final and definite conclusions.

XII. *On Diatomaceous Deposits in Scotland.*

By W. Ivison Macadam, F.C.S., F.I.C., Professor of Chemistry,
New Veterinary College, Edinburgh.

[Read June 24th, 1884.]

DEPOSITS of Diatoms have been long known to exist in Scotland, but such deposits have so far always been of limited extent. Specimens for the microscope have been readily obtained from certain localities, such as Peterhead, but the occurrence of large deposits covering great tracts of land was unknown.

In the year 1881 my attention was directed, by Mr. Hamilton Bell, to a white substance he had obtained from the Peat of Aberdeenshire. During April, 1882, I read a short paper before the Edinburgh Geological Society* in which I gave the analysis of a sample received from Mr. Bell, with particulars furnished by the Rev. Geo. Davidson, Minister of Logie Coldstone, Dinnet, who also kindly furnished a list of the Diatomaceæ he had identified in the deposit. The list contains some 200 species.

A further communication on the same subject was made by myself to the same Society at the January Meeting, 1883,† in which I gave the detailed analyses of samples received from the Black Moss, Kinnord, Ordie and Drum, all in Aberdeenshire, and from Gress, Isle of Lewis. A list of species as obtained by Mr. E. W. Burgess from the last named place is included in the paper. To these localities may be added deposits at Aros in Mull, Campbeltown; in Strath Cur, and in Glen Shira, Argyllshire; in Sutherlandshire, &c. &c.

The Black Moss, Aberdeenshire, deposit has been carefully investigated by the Earl of Aberdeen, to whom it partly belongs, and has been found to contain over 800,000 cubic yards, which amount is equivalent to about 150,000 tons weight. Ordie and Kinnord contain at least a like quantity. The deposit at Gress, Lewis, occupies a basin-shaped cavity, not many feet above sea-level, and is said to be more than 12 feet deep.

The Glen Shira deposit has not been as yet worked sufficiently to prove its extent, but from scattered notices (principally by Professor Gregory, of Edinburgh) I am inclined to consider it one of our largest deposits, and I intend to spend some time on the ground during August and September this year.

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* *Transactions Geological Soc of Edin.* Vol. IV. Part 3.

† *Trans. Geol. Soc. of Edin.* Vol. IV. Part 3, p. 277.

The material is sometimes obtained from Morasses or Lochs, but is more generally found forming a bottom layer or stratum underlying peat. This lower layer has long been known, and wherever peats have been cast in the Highlands the cutting is suspended when the "white layer" is reached. G. H. Kinahan also refers to this lower layer,* but does not mention of what it is composed.

When freshly cut the substance is brown in colour and very similar to the overlying peat, but when dried acquires a light gray colour. The material forms a light porous mass of Diatoms bound together by fragments of *Sphagnum*, *Equisetum limosum* and *E. fluviatile*, *Phragmites communis*, &c. &c.

I have made a careful series of analyses of the various deposits, and the results will be found in the tables at the end of the present paper. The proportion of siliceous matter (Diatoms with a few particles of sand) varies from 50 to 95 per cent., the remainder consisting of organic matter (woody fibre, &c.). The proportion of sand is very small, and in this respect the deposits compare favourably with the Kieselguhr obtained from the Continent. The Aberdeenshire specimens are also very free from iron, and yield on calcination a mass which has an absorbent power in excess of Kieselguhr in the following proportions:—

Kieselguhr (Lauenburg)	...	...	316
Sutherland Diatomite	...	...	381
Aberdeenshire ,,	...	...	639

or taking Kieselguhr at 1, the Sutherland deposit will be equal to 1·2, and the Aberdeenshire beds to 2·02.

This absorbent power is being largely taken advantage of in this country by Messrs. Nobel's Dynamite Company, who have to a great extent employed this substance in place of Kieselguhr, and with good results. Other uses, such as the artificial manufacture of Ultramarine, suggest themselves.

Analyses of Diatomite.

	Black Moss.			*Ordie Moss.*	
	No. 1. Margin.	No. 2. Centre.	No. 3.	No. 1.	No. 2.
Organic Matter	43·472	36·613	28·286	50·570	33·586
Inorganic Matter	56·528	63·387	71·714	49·430	66·414

	Drum Moss.	*Kinnord.*	*Lewes.*	*Sutherland.*
Organic Matter	4·779	22·371	13·874	13·08
Inorganic Matter	95·221	77·629	86·125	86·92

* *Geol. of Ireland*, Cap. 16, and *Journal of Science*, No. XLIII. July 1874.

Detailed Analyses of the Inorganic Constituents of Diatomite.

	Black Moss.			*Ordie Moss.*		*Drum Moss.*	*Kinnord Moss.*
	No. 1. *Margin.*	No. 2. *Centre.*	No. 3.	No. 1.	No. 2.		
I. *Soluble in Water.*							
Calcic Oxide	0·741	0·946	0·841	0·765	0·362	0·943	1·040
Magnesic ,, ...	0·332	0·552	0·548	0·482	0·371	0·456	0·606
Potassic ,, ...	0·076	0·213	0·224	0·187	0·108	0·315	0·327
Sodic ,, ...	0·048						
Sulphuric Anhydride ...	0·168	0·374	0·289	0·253	0·242	0·832	0·733
Chlorine	trace.	trace.	trace.	trace.	trace.	0·171	trace.
II. *Soluble in Acid.*							
Ferric Oxide	1·903	1·343	2·885	6·565	2·273	1·459	4·120
Aluminic ,, ...	0·236	0·429	0·407	0·201	0·154	1·104	1·854
Calcic ,, ...	2·737	2·692	2·484	2·897	0·782	2·378	0·998
Magnesic ,, ...	0·670	0·741	0·646	0·632	0·326	0·854	0·205
Alkalies	0·268	0·187	0·215	0·194	0·103	0·358	0·143
Phosphoric Anhydride	—	—	—	—	—	—	—
Soluble Silica ...	0·541	0·621	0·437	0·441	0·281	1·121	0·921
III. *Silicates decomposed by Hydric Fluoride.*							
Ferric Oxide	0·142	0·089	0·156	0·166	0·579	4·853	0·142
Aluminic ,, ...	0·535	0·202	0·342	0·383	0·463	4·404	0·303
Calcic ,, ...	0·114	0·132	0·127	0·155	0·432	2·136	0·058
Magnesic ,, ...	0·022	0·071	0·095	0·102	0·138	0·632	0·014
Silica (mostly Diatoms)	91·067	91·012	87·962	86·125	93·075	77·498	88·232
	99·600	99·704	99·658	99·548	99·689	99·514	99·696

XIII. *On the Age and Origin of the Metallic Veins of the Upper Harz.**

By H. M. Cadell, B.Sc., H.M. Geological Survey of Scotland.

(Communicated by the Rev. W. W. Peyton.)

[Read June 24th, 1884.]

Contents.—1. Topography; 2. Geology of the Harz Mountains; 3. Faults of the Upper Harz; 4. The Clausthal Veins; 5. St. Andreasberg Veins; 6 Suggested Origin of Veins.

1. The Harz Mountains rise from the great plain of secondary and tertiary formations in the western part of Prussia, about 130 miles inland from the seaboard at the mouth of the Elbe. Like the Thüringer Wald and other adjoining ranges, the Harz trends in an approximately east-south-east and west-north-west direction, and resembles on the map an elongated ellipse with a northern flattened side some 50 miles in length. It has been compared to a single mountain with large shoulders, culminating in the celebrated Brocken, 3,746 ft. in height. A line drawn through the Brocken from north to south roughly divides the region into two parts. The eastern division, drained by the Elbe, is rather flat and featureless. It has an average height of 1,600 ft., and is locally known as the Lower Harz (Unterharz). The Western or Upper Harz (Oberharz), drained by the tributaries of the Weser, rises to a height of about 2,000 ft., and is the seat of the great lead and copper mines for which the Harz Mountains have been for many centuries renowned.

2. The Lower Harz consists principally of graywackes, clay-slates and shales with Devonian fossils and some graptolites. The series has been named from the Harz *Hercynian*, and corresponds to Barrande's *Etages* F, G, H, which occupy a position intermediate between the Silurian and Devonian systems of the Bohemian basin. Patches of Devonian rocks occur at several parts of the Lower Harz associated with intrusive and interbedded diabases and tuff-beds.

The Upper Harz contains, in addition to Devonian sandstones, shales and limestones, a large area of graywacke and shale, which extends over

* An extended description of the geology of the Harz Mountains, with illustrations, map and sections, and with a list of the most important German papers on the subject, is given by the author in the *Proc. Roy. Phys. Soc. Edin.*, Vol. VIII., 1883-4, pp. 207-266.

the western and southern parts of the district, and was found by Murchison to be of Culm or Lower Carboniferous age. The Hercynian rocks are developed only in the south-western corner of the Upper Harz between Herzberg and St. Andreasberg.

The huge granite boss of the Brocken, believed by the old disciples of Werner to form the foundation of the "transition series," is one of the newest rock masses of the Harz. It rises as a great stock-like mass through the palæozoic formations, sending out apophyses or offshoots into the surrounding strata, which have been highly altered by the contact metamorphism produced in its vicinity.

Many dykes and bosses of basalt, diabase, kersantite, quartz- and orthoclase- porphyry, gabbro, syenite and enstatite rock traverse the palæozoic series, some of which are younger, but the majority either contemporaneous with, or older than, the granitic masses.

The palæozoic core of the Harz passes on its eastern, southern, and western sides underneath the slightly undulating formations of the plain. The old rocks are generally highly contorted, and strike as a rule north-east and south-west. The newer formations, beginning with the Upper Coal Measures and Red Permians, appear along the flanks of the Harz and rest in violent unconformability on the older strata. There must therefore have been a great upheaval and denudation between the time of the Culm and that of the Upper Coal Measures. The latter are generally overlapped by the red sandstones, shales and porphyrites of the Rothliegendes or Lower Permian group. These are in turn overlapped by the limestones and gypsum beds of the Zechstein or Upper Permian series which, along the western flanks of the Harz, creeps up over the Culm graywackes and completely conceals the underlying beds of the Rothliegendes.

The Harz is bounded on the north by a huge fault which runs for a distance of over 40 miles along the base of the mountains, and abruptly truncates the palæozoic rocks of the core. The edges of the secondary rocks are bent upwards and actually inverted along the line of fault, so that they appear to dip inwards below the mountains. The lowest beds are concealed, and no basal unconformability is to be seen on the down-throw side. It is only at Ballenstedt, near the eastern end of the fault, that the unconformability on the upthrow side has escaped removal by denudation. The Coal Measures and Red Permian sandstones are there found resting in a thin cake on the edges of the core rocks, in the same way that the Old Red Sandstone rests unconformably on the Highland schists on the north side of the great Caledonian fault between Crieff and Cortachy in Forfarshire.

Conglomerates containing pebbles of Harz rocks occur in the Coal Measure and Permian beds at Ilfeld on the southern side of the range. The highest of these conglomerates forms the basement of the Zechstein group, but from this horizon upwards to the tertiary deposits no trace of palæozoic detritus is to be found in any of the secondary strata. The ancient Harz must have begun to sink during the Permian period, and become completely submerged ere the Zechstein was all laid down. The emergence did not begin till the Cretaceous period, when signs of earth movement began to appear. The whole country was laid bare after the deposition of the Senonian or Upper Cretaceous group, and has since remained exposed to sub-aërial denudation, which has entirely removed the mesozoic covering as well as much of the palæozoic core below. The great brown coal deposits of Germany were formed in hollows or lakes during the Oligocene period, and one of these occurs in the neighbourhood of Thale and Blankenburg near the eastern end of the great fault. The brown coal here lies in a hollow, one end of which is clearly within the palæozoic area, and the other on the top of the Zechstein, which is here very thin and tilted up on end against the face of the fault. The fact of the deposit thus crossing or at least lying on the top of the line of dislocation, proves that the relative motion had entirely ceased previous to the Oligocene period.

3. The Upper Harz is traversed by a series of great faults which run through the highest Culm beds and also through the granite which pierces them. The faults must thus have been formed after the irruption of the granite. They run outwards to the edge of the range, and pass below the Zechstein, which abruptly cuts them off along with the quartz porphyry dykes which have sometimes risen along the lines of fissure. The faults are thus of Upper Carboniferous age, as they have evidently been formed between the time of the Culm and that of the Rothliegendes, when the porphyries were injected. They were certainly formed long before the Upper Permian period, as the Zechstein beds were laid down after the rock masses on each side of the faults had ceased to move, and had been planed off to an equal level by sub-aërial denudation. The series of faults runs from west to east past Clausthal towards Altenau. Similar faults cross the Bruchberg, a high spur of the Brocken between Clausthal and St. Andreasberg, and run into the St. Andreasberg mining district about 10 miles south-east of Clausthal, truncating or traversing the south-western end of the granite at that locality. The main faults at St. Andreasberg are generally parallel to those at Clausthal, and the two systems of dislocation are with good reason supposed to be contemporaneous in origin, although no faults have been actually traced the whole

distance from one locality to the other. If the faults which run westwards from Clausthal and pass under the Zechstein be thus contemporaneous with the Andreasberg faults farther east, the age of the granite is at once accurately determined. It must have been injected during the Upper Carboniferous period. The great metallic veins of the Upper Harz are in the fissures produced by these faults. The veins of the Clausthal plateau are either in the graywackes and "posidonomya shales" of the Culm, or else between Culm and Devonian rocks which, to the north of Clausthal, are brought together by a fault with a downthrow of over 100 fathoms.

4. The Clausthal veins are mined for lead, copper, and zinc, and are all very similar in mineralogical character. Dr. A. von Groddeck, Professor of Mineralogy and Geology, and Director of the Royal Mining Academy at Clausthal, is the author of one of the best existing works on Ore Deposits.* He has adopted the plan of classifying them according to certain types usually named after a locality where they are most strikingly developed. Veins similar in geological and mineralogical character to those of the Upper Harz are thus brought together under what he has named "Type Clausthal." This type is characterised by "Veins in stratified rocks of various ages, containing argentiferous galena, zincblende, copper and iron pyrites, with quartz, calcspar and chalybite in all proportions, barytes and other minerals occurring subordinately."

The Clausthal veins are large, sometimes reaching a thickness of over 130 ft. The footwall is sharply defined, but the hanging wall is usually shattered and rough, and passes into a fault-breccia containing fragments of graywacke and shale. It is a curious fact that calcspar is only found in the area north-east of the Innerste Valley and northwards from Clausthal, while barytes is confined to the portions of the veins traversing the western and south-western parts of the Upper Harz plateau. The ore is distributed in diagonal bands (*Erzfälle*) which slope towards the west, but occasionally occurs in vertical ribs (*Erzsäulen*) coinciding with the direction of hade, usually to the south. The same diagonal system of distribution obtains in the galena vein formerly mined at Tyndrum in Perthshire.†

The Clausthal mines are worked by the Prussian Government, and have now reached a depth in some shafts of 400 fathoms. There is a magnificent series of dressing works, to which the ore from the various mines is

* "Die Lehre von den Lagerstätten der Erze." Leipzig, Veit und Co. 1879.

† See description of the Tyndrum mines, by J. S. Grant Wilson, and H. M. Cadell, in *Proc. Roy. Phys. Soc. Edin.*, 1883-4, p. 195.

brought. A great subterranean canal, communicating with a main drawing shaft at the dressing floors, connects the underground workings, and serves both as a mode of transit for the ore and as an adit level to drain the mines in the Clausthal district. The most improved systems of mining and dressing the ores are adopted, and new apparatus is from time to time introduced. At Clausthal there is a Royal Mining Academy, where students are well trained in the theoretical as well as the practical branches of metal mining, and have altogether exceptional opportunities for visiting the numerous mines, dressing floors, and smelting works, on and around the Harz, to which they have at all times free access. Coal does not occur on the Harz in workable quantity, and water is largely used as a motive power. The whole plateau of the Upper Harz is dotted over with artificial ponds and reservoirs, many of which are picturesquely situated in sequestered spots among the fragrant pine forests with which the whole region is densely clothed. The water is brought in neatly cut channels from the ponds to the wheels and dressing floors at the mines. Many of the waterways are very long, one of them which comes from a shoulder of the Brocken reaching a length of some 16 miles. They wind pleasantly about among the forest glades, sometimes crossing a valley on the top of a high embankment, and at others plunging into a shaggy mountain side to reappear and resume the even tenor of their way in the valley beyond.

5. The celebrated silver veins of St. Andreasberg are all situated within an area resembling a very obtuse isosceles triangle whose base is about 4 miles in length. Two sides of the triangle are barren fault fissures (*faule Ruscheln*) full of soft fault-rock, made up chiefly of fragments of clay, slate and shale. These have a southerly hade and a breadth sometimes reaching 200 ft. The silver veins are thin, seldom exceeding half a yard in thickness. None of them pass out of the area just described: all outsiders are base, containing only copper pyrites and ironstone. The argentiferous veins run roughly in two directions: the first set, containing several veins, has an average strike of E 60° S and a steep hade to northeast, while the two veins of the second system run approximately E 15° S and hade to north at an inclination of 60° to 85°. In the network of veins thus formed are found the many rare and valuable minerals for which Andreasburg has so long been famous. The silver veins are filled chiefly with turbid white calcspar, which encloses grains, strings, and nests of quartz, and occasionally fluor, while splendid drusy cavities with crystallised calcite, apophyllite, and other zeolites, are often disclosed. The chief metallic minerals are galena, zinc-blende, native arsenic, ruby silver (pyrargyrite), antimony silver, arsenic silver, silver glance, smaltine, Breit-

hauptite and kupfernickel. The cobalt and nickel ores occur only in subordinate quantities. It has always been found that the silver veins become barren where they have a great thickness.

The Andreasberg veins are thus essentially different in mineralogical character as well as in dimensions from the great lead and copper veins of Clausthal. They resemble the veins of Przibram in Bohemia, and are cited by von Groddeck as examples of his "type Brand," named from a district near Freiberg where great numbers of such veins occur.

6. The origin of metallic veins has been explained by four theories—the *Congeneration theory*; the *Lateral Secretion theory*; the *Descension theory*; and the *Ascension theory*. Each is no doubt true in particular cases, but as a general rule the last three are alone applicable to the great majority of mineral veins. Of these the descension theory has perhaps the least support, but on considering the circumstances connected with the formation of the majority of the veins of the Upper Harz, it appears to me that perhaps this hypothesis is worthy of more attention than it usually receives.

The Harz formed part of a terrestrial area during the Upper Carboniferous and Lower Permian periods, as we have seen. The upturned and contorted Devonian and Lower Carboniferous strata were faulted and subjected to sub-aerial denudation, which went on till the beginning of the Zechstein or Upper Permian period, when the whole region became completely submerged. The highest of the conglomerates derived from the erosion of the ancient Harz occurs at the base of the Zechstein series. It is overlaid by the celebrated seam of Kupferschiefer or copper shale, extensively mined in the Mansfeld district at the south-eastern extremity of the range. The Kupferschiefer is only about 18 inches in thickness, but extends over a very large area, as it is found cropping out along the whole southern border of the Harz, and also on the flanks of the Thüringerwald, in Saxony. It is simply a bituminous shale containing small quantities of metallic sulphides in the form of very fine particles or powder. The chief minerals are copper and iron pyrites, erubescite, copper glance, silver glance, zinc-blende, galena, kupfer-nickel, and smaltine. Although the shale contains not more than 2 to 3 per cent. copper, and 0·01 to 0·20 per cent. silver, and the workable part of the seam is less than a foot in thickness, it is very uniform in quality over large areas, and the great difficulty and expense incurred in sinking deep shafts through watery strata is amply repaid by the value of the silver and copper extracted. The area in which the shale was deposited must have contained large quantities of metallic matter in suspension or solution. It was inhabited by an abundant fish fauna, represented by the species *Palaeoniscus Freieslebeni*,

and *Platysomus gibbosus;* many beautiful specimens of which are from time to time exhumed by the miners. The fine mud being deposited uniformly over the sea bottom, was mixed with particles of decomposing organic matter, which reduced and precipitated as sulphides some of the suspended metallic ingredients in the water.

The metals in the shale were no doubt derived from the denudation of rocks containing small quantities of metallic matter, in the form of silicates, oxides, or sulphides. Felspars have been found to contain small quantities of metallic matter, and as nearly all crystalline rocks contain much felspar, their decomposition would set free the metallic constituents. These would be carried off in solution if the water contained a sufficient quantity of solvents to prevent their immediate precipitation. Sulphides also occur abundantly, particularly in the palæozoic formations, and the Harz contains one very remarkable contemporaneous deposit of this character in the celebrated pyrites bed of the Rammelsberg, near Goslar. The ore deposit of the Rammelsberg is interbedded with upper Devonian shales, and has been disclosed to a longitudinal distance of 1,400 yards, a thickness sometimes reaching over 60 feet, and an extent along the direction of dip of nearly 1,000 feet. It consists of laminæ of copper, iron, and arsenical pyrites, with argentiferous galena, zinc-blende, fahlerz, and other minerals regularly interbedded, and partaking of the crumplings and folds of the surrounding rock. For aught that can be proved to the contrary, there may have been similar deposits in parts of the Harz and other districts, removed by denudation during the Permian period, which may have added considerably to the proportion of metallic matter in the Kupferschiefer lake.

When the Kupferschiefer was being deposited over the floor of the basin, the newly submerged faulted area must have been covered by the Zechstein sea, and the metalliferous fluids would have free access to the fissures below. The metallic ingredients in the shale probably represent only a small percentage of the total quantity originally suspended or dissolved in the water, and their precipitation was no doubt regulated by the quantity of organic matter set free. The deposit has evidently accumulated very slowly, and the fissures may have remained open to the metalliferous fluids for a very long period before a change of conditions stopped its further deposition, and the basin became part of a great salt sea on whose floor the overlying limestones and anhydrite beds were precipitated.

I am well aware of the many difficulties with which the hypothesis I have thus roughly sketched out is beset. I have ventured to bring it

forward merely by way of suggestion, as it seems to me there is much room for investigation into the origin of metallic deposits, from the point of view of the geologist as well as from that of the mineralogist and chemist. Too much faith is sometimes placed in the operation of imperfectly understood subterranean agencies, and this is an example of a possible explanation of perplexing phenomena by an appeal to known agencies which have acted at the surface, and can there be investigated with tolerable security and ease. I am quite prepared to see the theory very much modified, or even altogether rejected, but I think that sub-aërial agencies may have had more influence on the formation of metallic veins than is usually supposed, and that the Descension theory deserves more respect than it generally receives.

XIV. *The Origin of the Andalusite-Schists of Aberdeenshire.*

By John Horne, F.R.S.E., and Geological Survey of Scotland.*

[Read June 24, 1884.]

PERHAPS the most difficult question in the science of Geology at present, is the explanation of the origin of the metamorphic crystalline rocks which occupy large areas on the surface of the globe. These rocks have been generally regarded as having undergone a vast amount of change in lithological character, to which the term metamorphism has been applied. By local or contact metamorphism is meant the transformation which has been effected in ordinary sedimentary strata by the intrusion of igneous rocks, the extent of which depends on the relative size of the intrusive mass. Where a thin sheet of dolerite has been injected amongst Carboniferous strata, which is of common occurrence in the Scotch coalfields, the coal seam is frequently converted into anthracite. Where a large mass of granite has been intruded among Silurian rocks, as is the case in the south of Scotland, then the local metamorphism occurs on a larger scale. In the belt of strata encircling the granite masses in Galloway it is possible to trace the gradual passage of the greywackes, flagstones and shales, into quartzites, argillites and mica-schists, while the fossiliferous black shales become so altered within two miles of the granite that all traces of the graptolites are destroyed. The origin of this local metamorphism is therefore surrounded with little difficulty. It is different, however, with regional metamorphism. This term, which was first used by Daubrée, is intended to refer to those wide tracts of country which are wholly or mainly occupied by stratified crystalline rocks, such as gneiss, mica-schists, and quartzites. Various theories have been advanced in order to account for the origin of these crystalline rocks. By many geologists they are believed to be the altered representatives of ordinary sedimentary deposits, the nature and extent of the change being determined in a great measure by the chemical composition of the original sediment. This theory has been advocated by Bischof, Rose, Haidinger, Dana, and Sorby. An explanation has also been advanced which ascribes many of the metamorphic rocks to chemical precipitation.

* Published with the permission of the Director-General of the Geological Surveys.

The advocates of this theory maintain that the chemical ingredients necessary to form the various kinds of schist were held in solution and precipitated as sediments on the sea floor. The minerals now found in these schists crystallised during this sedimentation, and cannot be regarded as of subsequent origin. One of the ablest advocates of this theory is Dr. Sterry Hunt, and it has been supported with certain modifications by Gümbel, Delesse, and Scheerer.

The object of this brief communication is to show that the phenomena presented by the clay-slates and andalusite-schists of Aberdeenshire are quite at variance with the latter hypothesis. The clay-slate series, which is admirably displayed on the coast-line between Macduff and Gamrie, consists of well-bedded flags and shales, with occasional bands of quartzose grit and fine conglomerate. These beds cover a belt of country from eight to ten miles broad, stretching south-westwards from the sea-coast by the Culsalmond, Foudland and Kirkney Hills to the high grounds of Aberdeenshire. Over a large part of this tract the strata are nearly as unaltered as many of the Silurian rocks of the south of Scotland; indeed no one who is familiar with the appearances presented by sedimentary rocks could possibly doubt the sedimentary origin of the clay-slate series. Cleavage is more or less developed in many of the flags and shales, and in certain areas they are true slates.

On both sides of this belt of argillaceous strata there are zones of andalusite-schist, which stretch far into the country from the coast. At various points along the boundary lines between the clay-slates and the andalusite-schists it is possible to trace an intermediate zone of knotted schists, which are analogous to the rocks termed *Knotenschiefer* by the Germans. The detailed microscopic description of these different types of rock will be published at a subsequent date; but from a careful examination of a number of microscopic sections, it is clear that there is a gradual passage from the one to the other. In the rudimentary stage a rude foliation is developed, the quartz and mica being arranged in lines more or less distinct. The ordinary clay-slate merges at this stage into a slaty mica-schist. To this succeeds more perfect foliation, with the development of extremely minute ovoid knots or concretions, which under the microscope present few appreciable differences from the surrounding matrix. From the microscopic evidence it seems clear that they are formed by the segregation of portion of the matrix. Sometimes the knots are surrounded with a well-marked border or periphery, while again in other examples no border is visible. In the more advanced stages of alteration the matrix becomes more coarsely crystalline, the wavy outline of the mica-schist

being very apparent. There are two varieties of mica present, a brown, and a pale greenish coloured variety; the former of which exhibits marked dichroism. These are arranged in close bands with intervening quartz grains. The nodular segregations present certain differences from the surrounding matrix. They consist of an extremely fine-grained substance which has little action on polarised light, with some recognisable grains of quartz and mica. Along with these are abundant minute specks of a black substance resembling magnetite, which is also distributed throughout the rock. In the last stage of alteration the perfect rhombic prism of andalusite is observable in the soft mica-schist. Frequently the perfect prisms are associated with the knots in the same specimen, while in others the schist is studded all over with regular prisms. These *knotenschiefer* occupy extensive areas in the county, and present features of great interest. The gradual passage from the clay slates, which are truly sedimentary deposits, through the *knotenschiefer* into the andalusite-schists, seems to me to be quite at variance with the hypothesis of chemical precipitation advocated by Dr. Sterry Hunt; while it is satisfactorily explained by the theory of regional metamorphism established by Bischof.

XV. *The Mineral Albertite, Strathpeffer, Ross-shire.*

By W. Morrison, M.A., &c.

(Communicated by the Rev. W. W. Peyton.)

[Read June 24th, 1884.]

Chemical Composition.—This body is a hydrocarbon which has been classed under the Asphalt group ; but, unlike Asphalt, it does not melt at 100° C., nor is it at all soluble to the extent Asphalt is in such solvents as ether, oil of turpentine, benzol or carbon disulphide. When heated in a closed tube it shows incipient melting after intumescing, but, at the same time, it decomposes into its constituent gases. This chemical change takes place at 300° C. In the above solvents about 5 per cent. of bitumen is obtained. Carbon disulphide softens the mass throughout to a pasty consistence.

In 100 parts of Albertite there are of—

Volatile matter	62·00
Fixed Carbon	37·00
Water	·60
Ash, Sulphur	A trace.

Detailed analysis by Prof. Penny, C=79·75, H=8·12, N=1·63, O=10·30, Ash= ·20.

The chemical composition given by Boussingault for the black insoluble residue of Asphalt is C=75·5, H=9·9, O=14·8—giving the formula $C^7 H^{11} O$, and answers so far to the foregoing analysis by Penny, which I obtained from Sir James Mackenzie, Bart., of Findon, for whom the analysis was made. Albertite does not, however, behave like Asphaltene when treated with oil of turpentine. It does not easily dissolve, like Asphaltene, in oil of turpentine, or in naphtha, nor does it easily melt without decomposition at 300° C.

Physical Properties.—It becomes negatively electric by friction like amber and jet. It differs from jet by its superior lustre and conchoidal fracture. This lustre it loses after some use. It has been made into ornaments like jet, but its lack-lustre and brittleness are defects. It is much more porous than jet. Under the microscope it shows fine lamination on edge. The streak is black, not blackish-brown as in Asphalt.

The specific gravity of Albertite is 1·089, that of Asphalt is from 1·00 to 1·60. Altogether on chemical and physical grounds it must be ranked as a distinct genus of the hydrocarbon or mineral resins, intermediate between the coals and the asphalts. I consider it to be an oxidation product of petroleum.

Geological Position.—In the Strathpeffer district, Albertite is found in veins, of thicknesses varying from the thinness of writing paper to two and three inches thick. The veins in all cases are vertical or nearly so, and run horizontally east and west—strange to say in one invariable direction, no matter what the geological formation may be in which they are found, whether that be gneiss, micaceous sandstone, or conglomerate.

Attention, it seems, was directed to the existence of this mineral in 1825, by Witham (who visited Strathpeffer the previous year), in a paper read before the Wernerian Society of Edinburgh. According to Jameson's description of Asphalt, Witham classed Albertite as Asphalt, and specifically termed the Strathpeffer variety a "slaggy mineral pitch." Witham expressed astonishment at finding such a mineral in "primitive rock." The same mineral, according to Dawson (known as "Albertite" since his description of the variety found in Albert County, New Brunswick), is found at the base of the Carboniferous formation.

Between the gneiss, or metamorphosed Silurian of Murchison and Geikie, in which this mineral is found at the head of Strathpeffer Valley, and the compact micaceous and calcareous sandstone, in which it again appears farther down the valley, is that deposit of the bituminous shales which supply the famed Spa Wells of Strathpeffer with their characteristic constituents of sulphuretted hydrogen, and salts of magnesia, lime, &c. These shales are strongly impregnated with bituminous matter in the neighbourhood of the Albertite veins, and are thus suggestive of having a common origin with the mineral in question. Whether the bituminoid matter be the source of the mineral, or both are from a common origin, the fact of the presence of the mineral in the gneiss underlying these shales leaves open to question.

No Albertite veins are seen in the shales proper, and, where found, no bituminoid matter saturates the rock in which these veins are seen. The cracks in the Conglomerate of the Old Red, which in this district overlies the micaceous sandstone and the shales, and not underlying these, as commonly believed—are cut as clean, and sheer down through the mixed mass as if made by some gigantic knife. Those cracks only which run east and west contain the Albertite, quite as pure and as compact as in the

underlying sandstone. In cracks running in other directions no Albertite is found.

I am disposed to think that the shales interjacent between the underlying gneiss and the overlying sandstone and still higher conglomerate received their bituminoid matter from the same hypogene source, whatever that may have been. Doubtless superheated steam and air played a principal part in the process. The hydrogen, nitrogen, and oxygen of the substance are easily accounted for by this hypothesis, but whence the carbon?

XVI. *On the Occurrence of Prehnite and other Minerals in the Rocks of Samson's Ribs and Salisbury Crags.*

By Andrew Taylor, F.C.S., A.G.S.E.

(Communicated by the Rev. W. W. Peyton.)

[Read June 24th, 1884.]

WITH little else than the trouble of surveying one of the finest of Edinburgh landscapes, the tourist beginning work amongst the *débris* just to the south of where Samson's ribs overhang the road, and continuing on the road along Salisbury Crags to Holyrood Palace, will meet with a continuous display of the relations specially of zeolitic minerals, and their containing rocks. If he care to pursue the literature of the subject, Daubrée's investigations on the genesis of zeolites, as well as Allport's, Bonney's, and Geikie's petrological researches into the microscopy of the rocks in question, will suggest even more lengthened studies.

Good hand specimens of prehnite are easily obtained amongst the *débris* just mentioned, as well as in the two wall-veins betwixt the columnar pillars above it. Pectolite may also be got here. Large specimens in drusy cavities, such as adorn the magnificent suite of local minerals in the Edinburgh Museum of Science and Art, are only got at rare intervals, when rocks are being blasted for road making and the like. Thus the late Mr. Alex. Rose obtained such a specimen just above Samson's ribs when the Queen's Drive was being cut. The same local mineralogist obtained an equally handsome drusy cavity, filled with prehnite, analcime, and their allies, at the piercing of the Calton Hill Tunnel for the North British Railway. Specimens of the large analcimes, rather plentiful in 1818, when the dolerite quarries along the Radical Road were being worked into Salisbury Crags, adorn the Edinburgh Museum; but Mr. Thomas Allan carefully noted how these were got only when the quarrymen reached the centre of the dolerite bed: as if to anticipate the modern chemical hypotheses of the formation of these minerals, he noted the large proportion of calcareous matter both at the junctions of this bed with the sedimentary strata, as well as in the vents along its course.

Leaving Samson's ribs for the Radical Road, which skirts along Salisbury Crags to near the entrance of the Park at Holyrood, we may glance

in passing at the section of sedimentary strata in a hollow of the Queen's Drive just below the Echoing Rock. For these dolomites, cherty sandstones, and ferruginous clays, will be companions of our walk. They appear here to be cut off by the intrusion of Arthur's Seat itself; and the metamorphoses they undergo are classic representations of the unity of mineralogy and physical geology. The large deserted quarry at the eastern end of Salisbury Crags, containing Hutton's Pulpit with its upturned vein of hæmatite and calcite, demands a careful scrutiny. Just at its entrance, on climbing up the old spoil-bed, may be seen a white projection through the dolerite which I have elsewhere described as the South vent.* The rock here gives traces of cupric oxide. Towards the back of Hutton's Pulpit, white bounding veins of calcite and other matters cover exposed portions of the greenstone. These form bounding walls of the jointed masses; but the body of the rock is much looser than in the quarry above this one on our walk, indeed on microscopic analysis it shows a preponderance of calcite and zeolites in its composition, while along the footpath above the quarry, steam jet holes of $\frac{1}{4}$th of an inch or so are distinctly visible. This is Jameson's locality for datholite; though a careful search for boracic acid, by the writer, in the laboratory of the late Dr. George Wilson, in material got here for two months, does not predicate its abundance. Singularly enough, at Corstorphine Hill, another locality for prehnite, harmotome, and pectolite, datholite is also found. The prevalence of these zeolites and their allies in the augitic trappean rocks, as well as their absence from felspathic ones, are characteristic features of the geognosy round Edinburgh.

The "Cats-Nick" at a little hazard may be found a mineralogical treasure-house. Here, Thos. Allan† obtained barite, analcime, calcite, varieties of quartz in colour and form, as also of iron.

Fine specimens of chalcedony were got in a vein, which from its prominence strikes the eye beyond the old quarry, where the Radical Road joins the Queen's Drive beside Holyrood.

A visit to the old quarry in the Hunter's bog behind Salisbury Crags should be undertaken, if only to observe the large constituent quartz crystals of the sandstone.

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* *Trans. Ed. Geo. Soc.* Vol. III. pp. 279-291.

† *Trans. Ed. Royal Society*, Vol. VI.

XVII. *On Kyanite Localities in the North.*

By Thos. Wallace, High School, Inverness.

(Communicated by Rev. W. W. Peyton.)

[Read June 24th, 1884.]

THE parish of Engie in Banffshire lies on the south shore of the Moray Firth, to the East of the Spey. From the Spey to Buckie on the East the rock is Old Red Sandstone, which extends from the sea inland for about two or two and a half miles. This sandstone area is bounded on the south by a series of clay-slates and mica-schists. Both on the low and high grounds of this little parish, specimens of Kyanite were often picked up, sometimes associated with quartz, and sometimes with the schistose rocks of the district. So far as I have been able to determine, its position *in situ* was not known in the locality until I happened to stumble upon it in July 1882 (see *Trans. Geol. Soc.* Vol. IV. Part III. p. 269), after having examined the Old Red Conglomerates of the "Dramlachs," two streams near Fochabers, remarkable for the sections of conglomerate which they have exposed. Proceeding up the little "Dramlach," until the schist which has been exposed by the entire denudation of the Old Red Sandstone was reached, Kyanite was found *in situ*. The exact locality may be easily found by proceeding along the road from Fochabers to Keith, until the "Little Dramlach," which crosses the road, is reached; following this streamlet until a bridge is reached, Kyanite will be found in the rock on which the bridge is built. It may be remarked that these Eastern schists are in every way more interesting, mineralogically, than the Western or gneissose rocks of the Highlands.* They consist of clay-slates, mica-schists; andalusite, chiastolite, and kyanite-schists; associated with quartzites, serpentines, limestones, diorites, &c. At Portsoy and its neighbourhood the richness of these schists may be easily proved by the great variety of their mineralogical contents. It has been called by one well acquainted with the geology of the Highlands, "a perfect Mineralogical World." Kyanite is also found at Cotriphnie in Banffshire, and at Glen Urquhart in Inverness-shire. It is very plentiful in Glen Urquhart, where it is associated with serpentine,

* See *Geol. Soc. Trans.* Vol. III. Part III. p. 338.

anthophylite, Wollastonite, Biotite, chondrodite, edenite (brown and green), tremolite, actinolite, andesine, felspar, apatite, sphene, and zoisite.

Staurolite.—These Eastern schists also contain rutile, and I send a specimen of rutile from a new locality, Preshome, in the Engie. The specimen is by no means a good one, not so good as some that I have seen from this locality. It is plentiful here, and better specimens can easily be procured if wanted.

XVIII. *Note on Welsh Gold.*

By T. A. Readwin, F.G.S.

[Abstract.]

[Read June 24th, 1884.]

IN "*Notes on some Minerals of the Mawddach Valley, Merionethshire*," *Min. Mag.*, Vol. III. p. 122, I referred to their general auriferous character; and to the occasional occurrence of free or native Gold in workable quantity, often in states of Electrum, &c.

Since then I have been experimenting rather largely with the auriferous lode-stuff and its enclosing Silurian slate-rock, just at its junction with the coarse Cambrian (or, it may be, pre-Cambrian) sandstone, about 1,000 feet up the Gwynfynydd or white mountain, ascending from the beautiful waterfalls known to tourists as Pistyll-y-Cain and Rhiadr* Mawddach.

Recently I have made 22 trials upon 53¼ tons of the rocks and minerals by amalgamation, and extracted 44½ ounces of gold therefrom.

Altogether, at various times I have made 78 trials upon 72 tons from this mountain, resulting in 113½ ounces of gold, exclusive of rich stones reserved from the treatment, holding about 20 ounces of gold.

These trials were undertaken by me, primarily; to ascertain the relative and intrinsic values of the different minerals, next, an approximate average value, and lastly, the possibility by an eye-test simply, of casting aside some considerable bulk of them as being comparatively non-auriferous.

All this, to a satisfactory extent, I have done; and whilst doing it, have discovered several new and most interesting modes of gold occurrence which I purpose at another time to describe and exhibit to the Society. One of the richest specimens (weighing 160 grains) I have now the pleasure of submitting for examination, partly on account of its singular beauty, and partly in illustration of recent spontaneous gold-growth.

The gold in this beautiful specimen certainly had not its origin in pyritous matter; and it most certainly has undergone appreciable changes of shape since I discovered it last summer.

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* Both Pistyll and Rhiadr mean Cascade, on the rivers Cain and Mawddach.

XIX. *Note on New Locality for Zoisite.*

By W. Hamilton Bell.

(Communicated by the Rev. W. W. Peyton.)

[Read June 24th, 1884.]

IN the Article "Mineralogy," in the *Encyclopædia Britannica*, written by Professor Heddle, of St. Andrew's, that gentleman gives the formula of Zoisite :—

$$4\,CaO,\ 3\,Al_2O_3,\ 6\,SiO_2 + H_2O.$$

Alumina 29·8; Lime 24·35; Oxide of Iron 2·8; Silica 40·3; and Water 2·1.) Cleavage, brachy-diagonal, perfect: H = 6, G = 3·2 to 3·4. White, brownish gray, and dark green. Localities, Glen Urquhart, Dalnein (Grantown), and Alt Gonalan, Inverness-shire; Sterzing in Tyrol, the Sau-Alp in Carinthia, the Urals, and Connecticut.

Analysis of Zoisite from Loch Garve, Ross-shire, found by Mr. Hamilton Bell.

SiO_2	42·996
Al_2O_3	27·728
Fe_2O_3	2·469
CaO	24·163
MgO	1·403
K_2O	0·869
CuO	trace
	99·628

W. Ivison Macadam, F.C.S., F.I.C., Professor of Chemistry.

In March, 1883, I read to the Edinburgh Geological Society a Paper on matters of geological interest in Eastern Ross-shire, and in it I mentioned that, among other minerals, I had found one which I called Tourmaline. Being a young student even in geology, I was not sufficiently versed in mineralogy to feel satisfied that I was right in this nomenclature; and being at St. Andrew's in autumn last year, I mentioned the matter to Professor Heddle, and showed him a small specimen which I had with me. I had also found in Ross-shire another mineral which I was unable to name, and at Professor Heddle's request I sent him both specimens. I received from him an answer that "both specimens were the

mineral Zoisite," adding, "The brown is like what Dr. Arch. Geikie found at Dalnein Bridge, the white like what I found at Glen Urquhart; the white you have got is in larger crystals than I ever saw before in Scotland;" and then he remarked, "There must be limestone near Loch Garve."

The brown was found in the railway cutting on the Dingwall and Skye Railway, near the "Raven rock," where the rocks are all gneiss and mica-schist plentifully mixed with garnet (Almandine): the white I found in a siding for breaking stones for road metal, close to the station at Garve; and there was fully a ton weight there. I could not then determine its name; but I took away a large quantity. When Professor Heddle stated what it was, I got my friend Mr. Morrison, Rector of Dingwall Academy, to make further search in that neighbourhood, and at a point just above that road siding, and close to a distinguishable mass of pure white quartz, which I had marked, he also found the mineral, but stated that there were no signs of limestone in the neighbourhood, as suggested by Professor Heddle. I also sent a specimen of the brown to Dr. Archibald Geikie, who recognised it as Zoisite, stating "it is nearly identical with the Grantown (Dalnein) variety."

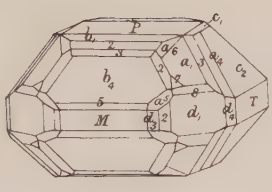


Fig. 1.

Fig. 2. Endellion.

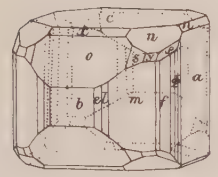


Fig. 3. Liskeard.

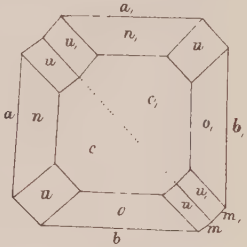


Fig. 4.

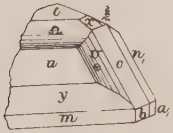


Fig. 5.

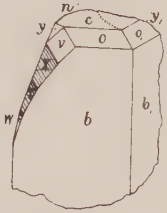


Fig. 6.

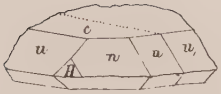
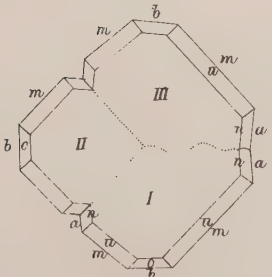


Fig. 7.

Fig. 8.



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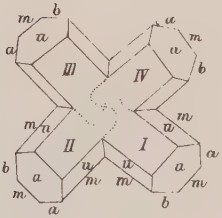


Fig. 10.

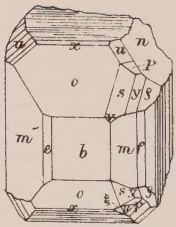


Fig. 11.

Fig. 12.

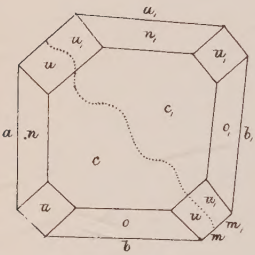


Fig. 13.

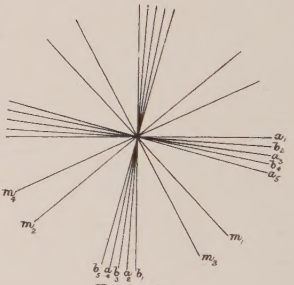
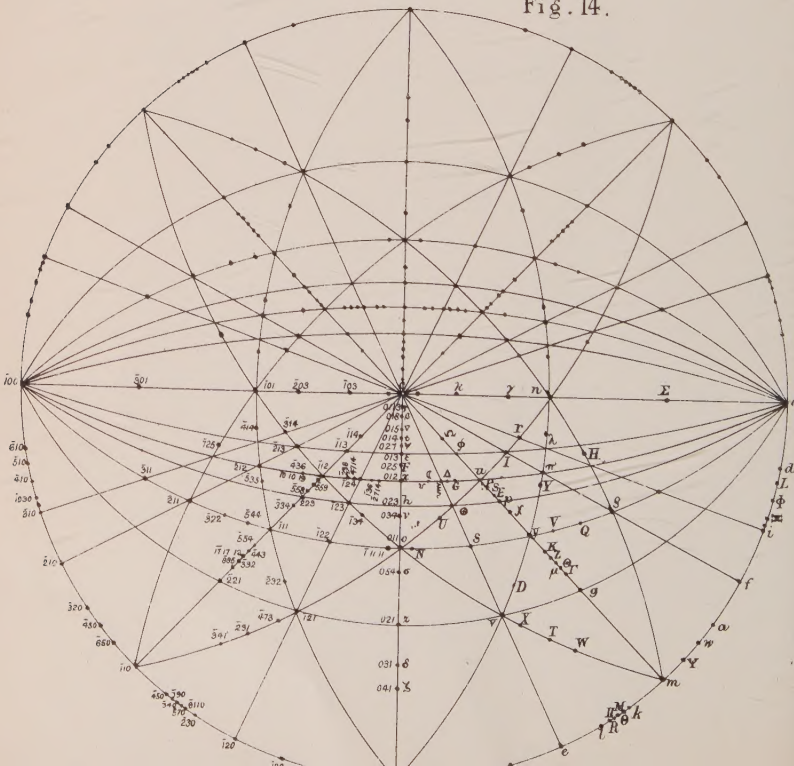


Fig. 14.



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